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TNO Science and Industry

Stieltjesweg 1
P.O. Box 155
2600 AD Delft
The Netherlands

www.tno.nl

T +31 15 269 20 00
F +31 15 269 21 11
info-IenT@tno.nl

TNO report

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VENOLIVA - Vehicle Noise Limit Values - Comparison of two noise emission test methods - Final report - DRAFT

Specific Contract No SI2.545143 implementing Framework Contract No ENTR/05/18

Date	13 August 2010
Author(s)	F. de Roo, MSc. M.G. Dittrich, MSc. P.J.G. van Beek, MSc. C. Bosschaart, MSc. G.B. Derksen, MSc. M. de Kievit, MSc.
Assignor	European Commission Enterprise & Industry Directorate General Automotive Industry, Unit ENTR/F/1 Attn. Mr. W. Schneider Av. d'Auderghem 45, 1040 Brussels
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Summary

The permissible sound level of road vehicles is part of the EU vehicle type approval legislation, as laid down in EU Directive 70/157/EEC [1]and in the UN-ECE Regulation No 51 [2], which specifies the test method for the noise emission test. Between 1990 and 1996 several studies showed that the test method, that had been in force with amendments since 1970, did no longer reflect the real life driving behaviour in urban traffic. In particular the contribution of tyre rolling noise to the total noise emission was underestimated in the test method. This fact was stated in official documents (e.g. the Green paper concerning the Future Noise Policy – 1996 [39]) and the development of a revised test method started.
The UN-ECE GRB (Groupe Rapporteur Bruit = Working Party on Noise) has published a new test method in 2007 with the purpose to monitor the application of this new method in parallel with the existing test method and to evaluate the qualities of the new method. During a period of three years the new method has been used for monitoring purposes. The monitoring period under UN-ECE Regulation No 51 lasted from 1 July 2007 until 1 July 2009, while the monitoring period under Directive 2007/34/EC [3] started on 6 July 2008 and expired on 6 July 2010. During the monitoring periods the results of the current and of the new test method were submitted to the European Commission. By this procedure a database of parallel test results has been collected that offers a good opportunity to investigate the qualities of the new method and to quantify the differences between the results of the two methods.

At the request of the European Commission, DG Enterprise and Industry, Unit F/1, Automotive Industry, TNO has executed a study into the differences between the current type approval test method A and the proposed new test method B.

The goal of the study was to "assess the available noise data in relation to the draft new test protocol and to provide possible new limit values for each category of vehicles, as well as for the derogations currently granted for certain types of vehicles."

The research questions that had to be answered by the study were:

a. What will be the effectiveness and the practicability of the new method B in comparison to the current method A?
b. How should the limit values for noise emission of the different vehicle categories be changed for each of five possible policy options:
   - *Policy option 1 – No change*
   - *Policy option 2 – New method – old limit values*
   - *Policy option 3 – New method – new limit values equivalent to old ones*
   - *Policy option 4 – New method – new limit values with noise reduction potential*
   - *Policy option 5 – New method – new limit values with noise reduction potential in two step approach*
c. How should the allowances that are currently in force for special vehicles (high-powered cars, off-road vehicles and vehicles with a direct-injection Diesel engine) be treated under a new system of limit values?
d. What will be the environmental, social and economical impact of each of the five policy options and of the revision of the system of allowances?

e. If the new test method is expected to cause problems for the efficiency of the noise measurements, how can the test method be modified in order to prevent these problems?
f. If the new test method cannot guarantee that the noise emission during other operating conditions than the test conditions does not exceed the test results significantly, what type of off-cycle provisions can be introduced to achieve this goal anyhow?

The most substantial part of the study was the statistical and acoustical analysis of the test result data that had been submitted to the European Commission. In addition to this many other data sources and literature concerning noise emission of vehicles were studied, a small enquiry among type approval authorities was held and the environmental, social and economical impacts of the five policy options were investigated.

One of the most important results of the study is the average difference between the test results with the current method A and the new method B for the different vehicle categories. This result is presented in Table 1 and Figure 1:

Table 1 - Average difference between noise emission test results according to method B and method A per vehicle category

Category	Description	Total number of vehicles	Average difference of test results: method B – method A
			[dB(A)]
M 1	Passenger car	653	-2,1
M 1G	Pass. car – off-road	24	-2,3
M 2	Medium-sized bus	28	-1,0
M 3	Heavy bus	76	-0,7
N 1	Van	52	-1,7
N 1G	Van – off-road	3	-1,2
N 2	Medium-sized truck	55	-1,2
N 3	Heavy truck	100	+1,2
N 3G	Heavy truck – off-road	39	+0,6
Total		1030	-1,5

Limit values
Based on the differences between the average results of the methods, the correlations between the results and the distributions of the results of method B, proposals were drafted for the specification of limit values under the five policy options. For each of these options and the corresponding limit values, the predicted change of the noise emission of the different vehicle categories in normal traffic was assessed. From these emission changes, the changes in noise impact and in the prevalence of noise annoyance and sleep disturbance in the population were estimated.

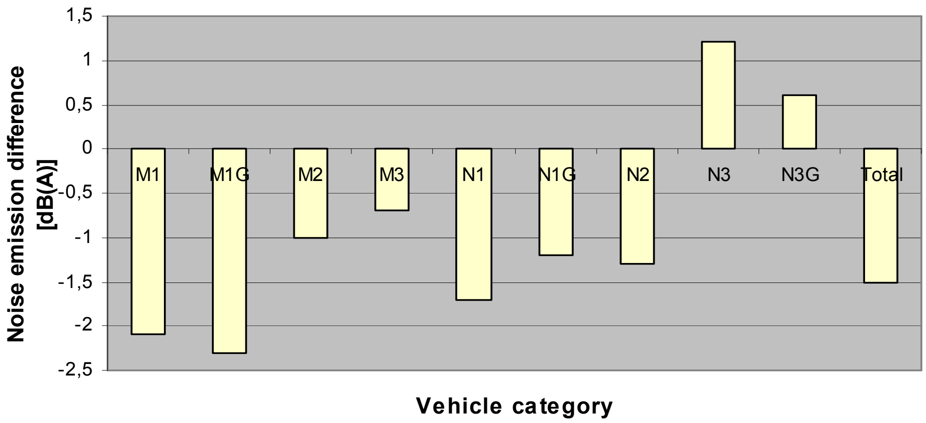


Figure 1 - Average difference between the test results of methods B and A per vehicle category.

Impact assessment
The environmental benefit in terms of noise levels is greatest for options 4 and 5, with reductions in L_{DEN} and L_{night} on average 2,5 dB for option 4 and 3,1 dB for option 5. Higher reductions are reached for roads with intermittent traffic where powertrain noise is dominant, 2,8 dB for option 4 and 4 dB for option 5.

The social impact in terms of numbers of highly annoyed people and highly sleep disturbed people is significant. For the current situation (option 1) an estimated 55 million people are highly annoyed by road traffic and 27 million are highly sleep disturbed. These numbers are reduced to 44 / 22 million for option 4 and 41 / 22 million for option 5.

The economic impact consists of benefits to society due to reduced traffic noise and costs for the vehicle industry due to reducing noise levels of vehicles, in particular the powertrain noise, as tyre noise will be reduced due to the tyre directive. The impact on the vehicle industry consists primarily of additional development and production costs due to extra reduction of powertrain noise on vehicles.

For option 4 the accumulated costs amount to 5 billion Euros and 7,7 billion Euros for option 5. These costs are incurred over a development and production cycle of 3+7 years and consist mainly of additional production costs which are no longer incurred after 10 years.

The accumulated benefits for society consist of valuation of noise reduction, healthcare savings and savings on noise abatement on road infrastructure and dwellings. By far the largest benefits are due to hedonic pricing related to perceived value of noise reduction, followed to a lesser extent by healthcare savings and relatively smaller savings on noise abatement costs.

Together, these benefits are in the order of 101 billion Euros for option 4 and 120 billion Euros for option 5 over the period 2010-2030. The benefits outweigh the costs for industry by a factor 20,1 for option 4 and a factor 15,7 for option 5. The environmental and social benefits may be reduced by half if traffic growth continues at current rates.

Evaluation of test method B
The evaluation of method B provided a positive conclusion about the representativeness and practicability of method B, although some shortcomings of the method were reported. Therefore recommendations are given for amendments of the method concerning the maximum acceleration during the test, the instructions for the choice of gears for lockable automatic transmissions and the loading of heavy vehicles.

Need for off-cycle provisions
Furthermore it was concluded that the representativeness of method B for the noise emission during normal traffic conditions is good, but that it is less representative for noise emissions under worst case conditions. Therefore it is recommended to implement a form of off-cycle emission provisions. Based on an analysis of the ASEP (Additional Sound Emission Provision) methodology, that is currently under development in the GRB Informal Group ASEP, the further development of ASEP - method 2, with several modifications, is advised.

Evaluation of current allowances
The evaluation of the current allowances for higher noise emissions from some special sub-categories of vehicles provided the following conclusions:
- The allowance for direct injected Diesel engines should be cancelled;
- The allowance for high-powered passenger cars should be maintained with a revised criterion for the qualification high-powered;
- The allowance for off-road vehicles should be maintained with some modifications.

Recommendation for revised limit values
After balancing the benefits and the costs, policy option 5 is recommended for implementation, in combination with the introduction of test method B for type approval of vehicles.

The proposed limit values for policy option 5, in combination with the revised formulation of the allowances, has been elaborated into a proposal for the amendment of Article 2 of Annex I of Council Directive 70/157/EEC, which specifies the limit values for the noise emission of vehicles. This proposal can be found on page 105 of this report.

Contents

1 Introduction

The permissible sound level of road vehicles is part of the EU vehicle type approval legislation, as laid down in EU Directive 70/157/EEC [1]and in the UN-ECE Regulation No 51 [2], which specifies the test method for the noise emission test.
In 1996 it was stated in the Green Paper on the Future Noise Policy [39] that tyre noise had become more significant and with the new noise emission limits introduced in 1996 would be the main noise source at speeds above 50 km/h. The point had now been reached where without action to address tyre/road noise, a further lowering of the limits would not be effective. Also the 1992 amendment of EU Directive 70/157/EEC called on the Commission to present a proposal to address the problem of tyre/road noise in the type approval test.
These statements were based on the findings of several studies that the test method, that had been in force with amendments since 1970, did no longer reflect the real life driving behaviour in urban traffic. Therefore the UN-ECE GRB (Groupe Rapporteur Bruit = Working Party on Noise) has published a new test method in 2007 with the purpose to monitor the application of this new method in parallel with the existing test method and to evaluate the qualities of the new method. During a period of three years the new method has been used on a provisional basis for monitoring purposes. The monitoring period under UN-ECE Regulation No 51 lasted from 1 July 2007 until 1 July 2009, while the monitoring period under Directive 2007/34/EC [3] (amending Dir 70/157/EEC) started on 6 July 2008 and expired on 6 July 2010. During the monitoring periods the type approval authorities were obliged to execute the noise emission tests according to both methods and to submit the results of both tests to the European Commission; only the results of the current test are valid for the type approval. By this procedure a database of parallel test results has been collected that offers a good opportunity to investigate the qualities of the new method and to quantify the differences between the results of the two methods.

At the request of the European Commission, DG Enterprise and Industry, Unit F/1, Automotive Industry, TNO has executed a study into the differences between the current type approval test method A and the proposed new test method B (see Chapter 3).

The goal of the study was to “assess the available noise data in relation to the draft new test protocol and to provide possible new limit values for each category of vehicles, as well as for the derogations currently granted for certain types of vehicles.”

TNO performed this study on behalf of a consortium operating under Framework Service Contract ENTR/05/18.

This report gives an account of the methods that were used in this investigation, of the results that were achieved and of the conclusions and recommendations concerning the necessary or possible changes to the noise emission type approval legislation, aiming at a procedure that will be effective and efficient in terms of environmental, social and economic impact.

2 Questions to be answered by this study

The Terms of Reference for the study were laid down in a Service Request from the EC to the consortium operating under Framework Service Contract ENTR/05/08.
The research questions formulated in the Service request may be summarised as follows:

g. What will be the effectiveness of the new method B in comparison to the current method A, in terms of:
    - practical applicability;
    - representativeness of the test results for the noise emission of road vehicles under urban driving conditions;
    - significance of the test method: to what extent can the new test method prevent that the noise emission under other operating conditions than the test conditions exceeds the test results significantly;
    - possibilities to prevent adaptation of the vehicle and its engine control unit to the test conditions;
    - control of the selection of test tyres

   The findings on this research question are discussed in Chapter 8.
h. How should the limit values for noise emission of the different vehicle categories be changed for each of the following policy options:
    - No policy change (current test methods; no change in limit values);
    - New test method with the current limit values;
    - New test method with new limit values, such that they will not lead to stricter requirements than incorporated in the current test method and limit values;
    - New test method with new limit values, aiming at a reduction of the authorised noise emission per motor vehicle;
    - New test method with new limit values, aiming at a reduction of the authorised noise emission in a two step approach: the first step will enable a recognisable noise reduction while being implementable within 3 to 5 years; the second step will aim for a more ambitious noise reduction over a longer period.

   The proposed limit values for the 5 policy options are set out in Chapter 6.
i. How should the allowances that are currently in force for special vehicles (sports cars, off-road vehicles and vehicles with a direct-injection Diesel engine) be treated under a new system of limit values: should they be maintained, replaced by new sub-categories or cancelled?
   The answer to this question is given in Section 6.2.
j. What will be the environmental, social and economical impact of each of the five policy options described under b. and of the revision of the system of allowances described under c.
   In Chapter 7 the impact assessment is presented.
k. If the new test method is expected to cause problems for the efficiency of the noise measurements, how can the test method be modified in order to prevent these problems?
   The answer to this question is given in Chapter 8.
l. If the new test method cannot guarantee that the noise emission during other operating conditions than the test conditions does not exceed the test results significantly, what type of off-cycle provisions can be introduced to achieve this goal anyhow? This issue is discussed in Section 9.

3 Main characteristics of the current and the new noise emission test method

3.1 Test method A – UN/ECE Regulation 51 – Addendum 50 – Rev 1 – Annex 3

The currently applicable method 'A' for vehicle noise measurement procedure and accompanying limit values are described in detail in Annex 3 of UNECE R51 [2], from which the measurement method is based on ISO 362 [4]. It was developed as a test under worst case urban conditions, i.e. full throttle acceleration in urban areas.

For passenger cars this method comprises the following:

- The test track consists of a 20m long tarmac pavement according to ISO 10844 [5], which is a very smooth and quiet road surface.
- Halfway along either side of this track a microphone is placed at a distance of 7,5m from the centre line, 1,2m above the ground.
- The vehicle has to enter the track at 50 km/h and then accelerate with wide open throttle (WOT) in the specified gears, mostly 2nd and 3rd gear for 'normal' passenger cars, until the end of the 20m long track.
- During the pass-by, the exponentially time averaged A-weighted sound level L_{pAF} at both microphones is measured, from which the maximum L_{WOT} of the complete pass-by is used for further processing.
- Finally, after several runs the reported sound level is the average of the $L_{A,max}$ of the test runs in both 2nd and 3rd gear.
- This $L_{A,max}$ should be below the limit value.

For other types of vehicles the test is similar, although the approach speed, prescribed gears and other details can differ per vehicle category.

3.2 Test method B – UN/ECE Regulation 51 – Addendum 50 – Rev 1 – Annex 10

The aim of the new method 'B' was to develop a 'design independent' measurement method and to better represent urban driving conditions in general. Therefore this method consists of both an acceleration and a constant speed test. The acceleration test differs significantly and is much more complicated than the WOT acceleration test from method A. It is described in detail in Annex 10 of R51 [2] and in general for passenger cars, mini-van buses and light commercial vehicles (vehicle categories M1, M2 < 3,5 t and N1) the procedure is briefly as follows:

- The vehicle has to enter the test track with such a speed, that after WOT acceleration a speed of 50 km/h is reached at the microphone cross section, i.e. halfway along the test track.
- Several preparatory test runs are made in order to determine the right gear ratio to achieve the required acceleration.
- The speed of the vehicle is measured at the entrance and the exit of the track, from which the average WOT acceleration a_{WOT} can be determined.
- With this a_{WOT} the gear is determined, in which the required WOT test acceleration $a_{WOT,ref}$ can be reached as accurately as possible. This $a_{WOT,ref}$ can be calculated with a formula given in the Annex 10 and is related to typical urban acceleration a_{urban}. Both accelerations are a function of the power-to-mass ratio (PMR) of the vehicle and derived from statistical investigations.

- If there is no gear in which the target acceleration $a_{WOT,ref}$ can be reached within the prescribed tolerance band, test runs in one gear higher have to be included.
- For each individual gear, the exponentially time averaged A-weighted sound level L_{pAF} at both microphones is measured during the pass-by, from which for each gear the maximum L_{WOT} of the complete pass-by is used for further processing.
- The final WOT acceleration sound level $L_{WOT\,rep}$ is the weighted average of the L_{WOT} in each gear, were the weighting factor depends on the differences between the achieved accelerations in the different gears.

In case of the constant speed (or cruise-by) test, the procedure is as follows:
- The passenger car passes the test track at a constant speed of 50 km/h in the same gear(s) as used for the acceleration test.
- During the pass-by the $L_{crs,}$ is determined from the maximum of the measured sound levels at both sides of the vehicle.

Finally the total urban sound level L_{urban} is a weighted summation of the sound levels from the acceleration and constant speed test, were the weighting factor depends on the ratio between the urban acceleration a_{urban} and the reference acceleration $a_{WOT,ref}$. This L_{urban} should be below the future limit value.

For M_1, N_1 and $M_2 \leq 3500$ kg vehicles, a flow chart of the gear selection procedure in method B is given in Appendix A.

For other categories and types of vehicles the test procedure is less complex. The WOT acceleration test has to performed within a target engine speed range and a target vehicle speed range instead of a target acceleration. Testing can be done in one gear if the target ranges are reached in this gear. If no gear fulfils the target condition for the vehicle speed, two gears shall be tested: one below and one above the prescribed vehicle speed range. Furthermore the constant speed test is not included for these vehicle categories, so the final test results is only based on WOT acceleration testing.

Although most measurement conditions (test track, microphone positions, meteorological conditions, etc.) are equal to method A, there are some striking differences between the two methods:
- To allow for lack of measurement equipment precision in method A, all the measured sound levels (intermediate results) have to be reduced by 1 dB(A), whereas in method B all intermediate results are rounded to the first decimal and no reduction is applied at all.
- In method A the minimum required tyre tread depth is 1.6mm, whereas in Method B the tread depth has to be at least 80% of the full depth. This can result in an increase of several dB of the tyre-road noise component, especially for tyres with a rough tread pattern.

4 General methodology of the study

4.1 Data gathering and analysis

A main part of the study consists of a statistical and acoustical analysis of the type approval test data that have been submitted to the EC during the combined three years monitoring period. In total 1029 files were submitted and stored in a database at the EU Circa web site, that was accessible to authorised persons. 36 of these files could not be included in the data analysis, because pages were missing or the file format was not in line with the requested format. On the other hand, many of these files contained the data of more than 1 vehicle. After conversion of all convertible files 1064 files of single vehicles were available. Of this set, 34 files had to be put aside because no vehicle category was specified, essential data (test results of test A or B, engine capacity, engine power or power to mass ratio) were missing and could not be retrieved or the file was a duplicate of another file in de database. The distribution of the submitted, converted and analysed data files over the different vehicle categories is given in Table 2. The files concerning off-road vehicles were not stored separately at the Circa website, but were included in vehicle categories M1, N1 and N3.

Table 2 - Distribution of vehicles in the Circa database and in the analysed data files

Vehicle category	Informal category description *	Number of files in Circa database	Converted single vehicle files	Analysed single vehicle files
M1	Passenger car	670	660	653
M1G	Passenger car for off-road use	-	26	24
M2	Medium-sized bus	3	28	28
M3	Heavy bus	56	76	76
N1	Small van	51	52	52
N1G	Small van for off-road use	-	3	3
N2	Medium-sized van / lorry	34	58	55
N3	Heavy truck	179	118	100
N3G	Heavy truck for off-road use	-	39	39
Subtotal		**993**	**1060**	**1030**
	No category specified	-	4	4
	Essential data missing	-	-	18
	Duplicate file	-	-	12
	Deviant format; missing pages	36	-	-
Total		**1029**	**1064**	**1064**

* The formal definition of the vehicle categories can be found in Annex II of EU Directive 2007/46/EC [6].

As the data of the vehicles were contained in separate files and as the files had different formats, all files had to be transferred into one single master XLS -file that could serve as an input file for the statistical analysis software package GenStat 10.2 that was used for sorting and analysing the data. The basic files consisted of three pages for each vehicle (see Appendix E): a page with general vehicle specifications, a page with the results of test method A and a page with the results of test method B. When the transfer activities started it appeared that there was a large variation in the way the basic files had been filled in, that there were many omissions and errors in the submitted data and that some submitting organisations had changed the files to make them comply with their own needs. Therefore extensive data cleaning and data correction had to be carried out in order to bring the data in a uniform data format and in a uniform terminology, so as to be able to execute the analyses. The cleaning and correction activities were carried out using a general knowledge of vehicle technology and of the test procedures of the methods A and B and making use of the technical specifications of the vehicles that could be retrieved from the manufacturers' websites.

Also many of the submitted files appeared to contain data pages of more than one vehicle, sometimes upto 10 vehicles. These files were split into the different vehicle variants and included separately in the master XLS-file. 33 files did not contain results of the current test method A. A list of the vehicles involved in these files was sent to the vehicle manufacturers association ACEA with a request to supply the missing test results if these were available at ACEA. 31 files could be completed with additional information received from ACEA.
The data analysis was executed on a master file that contained a total number of 1023 vehicles, distributed over the vehicle categories as indicated in Table 2.

In the analysis many statistical parameters were determined on various selections of vehicles. The results of test method A, test method B and the difference between B and A were determined as a function of engine capacity, maximum engine power, power to mass ratio, engine type (Compression Ignition [= Diesel] or Positive Ignition [= Petrol = spark ignition], gear box type (manual transmission, automatic transmission, CVT [Continuously Variable Transmission]).
The results of this analysis are discussed in Chapter 5.

4.2 Elaboration of policy options for limit values

Based on the results of the analysis described under 4.1 the 5 policy options described in question h. in chapter 2 were elaborated as follows:

4.2.1 Option 1

In this option there is no policy change: the old test method will remain in use with no change to limit values. For this option no elaboration of the limit values was necessary.

4.2.2 Option 2

In this option the new test method will be used with the existing limit values. In this case, also no elaboration of the limit values was necessary. As a consequence of the findings on the relevance of the current allowances to the limit values for special vehicle sub-categories (Chapter 2 – question i) the existing limit values were copied with a number of modifications on these allowances.

4.2.3 Option 3

This option aims at the use of the new test method in combination with new limit values, such that they will not lead to more severe requirements than incorporated in the current test method and limit values. For the elaboration of this option the analysis results of section 5.2 were used to derive new limit values that will result in a level of requirements equivalent to the old system. The information used to derive the new limit values incorporated the differences between old and new test results, the regression equation of the new test results expressed as a function of the old results, the percentage of non-compliant vehicles under the new limit values and the evaluation of the allowances for special vehicle sub-categories (see further section 6.3.3).

4.2.4 Option 4

The limit values proposed in option 4 were to be aimed at a reduction of the authorised noise emissions per motor vehicle. In order to develop limit values that would be effective and feasible, the average noise emission reduction that will result from the lowering of the limit values for rolling noise of tyres was determined. From an analysis of how this rolling noise reduction will influence the future test results, it was assessed which level of limit value reduction would feasible, taking into account the percentage of non-compliant vehicles for different limit value reductions and the relevance of the allowances for special vehicle categories (see further section 6.3.4)

4.2.5 Option 5

In option 5 the same approach as in option 4 was followed, but in this case the final noise reduction objective was to be achieved in a two-step approach. In the first step a moderate reduction of the limit values was sought that would exclude a limited percentage of vehicles from passing the test. In a second step, some years later, the limit values would be reduced again resulting in higher percentage of the vehicles that would no longer pass the test and should be modified. The values of the reduction steps and the time schedule for the reduction were proposed based on the non-compliance percentage for different limit value reductions (see further section 6.3.5).

4.3 Impact assessment

The impact assessment covers the environmental, social and economic aspects of the five policy options. It is consistent with the EU Impact Assessment Guidelines (IAG) 2009 [35]. The analysis takes the five policy options as a starting point and covers the required IA parts ‘Analysis of Impacts’ and ‘Comparing of Options’. EU position papers, WHO guidelines, Eurostat reports and other European and national research reports are used as starting points and inputs for parts of the analysis.Several parties including ACEA were consulted to strengthen the basis of the study.

As the various impacts are not all quantifiable or lacking data, the impact assessment is first performed in a qualitative way. This is followed by a quantitative analysis of the main impacts based on available data, of each policy option. The environmental impact is defined in terms of reduction of L_{DEN}, L_{night} and single event levels. The social impact is described in terms of reduced annoyance, sleep disturbance, health effects, quality of life and reduced need for traffic noise abatement. The economic impacts and the cost benefit analysis are quantified based on estimates for the benefits to society and costs to industry.
The analysis and results of the impact assessment are discussed in Chapter 7

4.4 Evaluation of the new test method B

The practicability and manageability of test method B was investigated by means of an enquiry with a short questionnaire among a number of type approval authorities that had submitted significant numbers of test report files for the database. In addition to the information obtained with this questionnaire and based on the first practical experiences with the method, the results stored in the Circa database were used to determine the balance between power train noise and tyre rolling noise, to assess the range of results per vehicle category and to verify whether the influence of tyre characteristics on the test results of heavy trucks was included in a relevant way.

4.5 Off-cycle provisions

The different possibilities for the introduction of an off-cycle emission regulation were studied on the basis of available literature, primarily originating from the UNECE GRB Informal Group on ASEP (Additional Sound Emission Provisions).
The 2 methods for ASEP developed within the framework of GRBIG ASEP were analysed in relation to the objectives for an off-cycle provision regulation and recommendations for improvement of the most promising method were formulated.

5 Results of the database analysis

5.1 Inventory of characteristics of vehicles in the database

5.1.1 Vehicle categories

As already shown in Table 2 in 4.1 the largest number of vehicles (653) belonged to category M1, the passenger cars, followed by category N3, trucks (100). Other categories showed considerably lower numbers as can be seen in Table 3.

N.B.1 In other tables sometimes lower numbers of vehicles are presented due to missing values of particular variables.

5.1.2 Mass of the vehicles

The determination of the mass may be different in the cases of method A and method B. In Table 3 the range of masses determined according to both methods is given.

Table 3 – Total numbers per vehicle category and ranges of vehicles masses according to method A and method B in database.

Category	Description	Total number	Mass acc. to method A (kg)		Mass acc. to method B (kg)	
			Minimum	Maximum	Minimum	Maximum
M 1	Passenger car	653	848	3500	848	2857
M 1G	Pass. car -off-road	24	1695	3080	1695	2714
M 2	Medium-sized bus	28	1715	3085	1715	3085
M 3	Heavy bus	76	1960	18100	1960	18100
N 1	Van	52	1276	3500	1276	5584
N 1G	Van – off-road	3	1990	2660	1987	2660
N 2	Medium-sized truck	55	1960	5600	1960	12260
N 3	Heavy truck	100	4535	14715	3723	18840
N 3G	Heavy truck – off-road	39	7470	22980	13000	22980
Total		1030				

5.1.3 Body type

The body type of the vehicles was indicated in the data files in many ways, but has been converted into the terminology according to Dir 2007/46/EC Annex II [6]. The body types present are given in Table 4.

Table 4 – Numbers of body types per vehicle category in the database

Body type	Description	Vehicle category										
		M 1	M1G	M 2	M 3	N 1	N1G	N 2	N 3	N3G	No data	Total
AA	Saloon	164										164
AB	Hatchback	136	1									137
AC	Station wagon	155	21									176
AD	Coupé	63										63
AE	Convertible	45										45
AF	MPV	85	1									86
BA	Lorry		1	6		21	2	44	84	33		191
BB	Van	1				31	1	10				43
BC	Semi trailer towing vehicle							1	8	5		14
BD	Road tractor								7	1		8
CA	Single deck bus (Class I)				3							3
CE	Single deck bus – low floor (Class I)				31							31
CM	Single deck bus – low floor (Class II)				2							2
CQ	Single deck bus (Class III)			2	33							35
CV	Single deck bus – low floor (Class A)			1								1
CW	Single deck bus (Class B)			19	6							25
SC	Ambulance	3										3
	No data								1		3	4
	Grand total	652	24	28	75	52	3	55	100	39	3	1031

5.1.4 Engine and drive train characteristics

The distribution of engine type, gear box type and driving axle system is given in Table 5.

Table 5 – Numbers of engine type, gearbox type and driving axle per vehicle category in the database.

Category	Engine type		Gear Box type			Driving axle			No data	Total
	Petrol (Positive Ignition)	Diesel (Compression Ignition)	Manual	Auto-matic	CVT	Front	Rear	Front +rear		
M 1	389	269	434	218	6	509	74	71	4	658
M 1G	8	16	11	13		2		22		24
M 2	1	27	22	6		8	18	2		28
M 3	6	70	26	49	1		76			76
N 1	9	43	42	10		27	20	5		52
N 1G		3	2	1			1	2		3
N 2		55	43	12		1	54			55
N 3		100	39	61			100			100
N 3G		39	32	7			17	22		39
No data	1								3	3
Total	414	621	651	377	7	547	360	124	7	1038

The ranges of the specific characteristics of the engines (capacity, maximum power, power to mass ratio (according to method A and B)) are given Table 6.

Table 6 – Ranges of engine capacity, maximum engine power and power to mass ratio per vehicle category in the database.

Category	Engine capacity [cm^3]		Maximum engine power [kW]		Power to Mass Ratio Method A [kW/ton]		Power to Mass Ratio Method B [kW/ton]	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
M 1	799	6208	33	493	29	293	34	293
M 1G	1390	4999	93	298	50	107	50	120
M 2	1910	2998	62	132	31	73	31	73
M 3	2143	12816	93	331	14	21	14	21
N 1	1461	3933	50	132	29	73	19	73
N 1G	1986	2999	110	131	41	66	41	66
N 2	2143	6871	65	249	28	45	20	32
N 3	6700	16350	184	537	29	51	20	27
N 3G	10837	16160	240	500	22	47	22	25
No data	1984	1984	155	155				
Grand total	799	16350	33	537	14	293	14	293

5.2 Results of noise emission tests according to methods A and B

5.2.1 Results per vehicle category

With the exception of a small number of vehicles, the final test results of noise emission tests according to method A and B were specified in the database files, together with intermediate results and values of the vehicle performance parameters during the test. In Table 7, Table 8, Table 9, Figure 2 and Figure 3 the test results of method A, method B and the difference B-A are presented per vehicle category with the following values: (arithmetical) mean, minimum, maximum and median (the centre of the distribution).

Table 7 – Noise emission test results according to method A per vehicle category

Vehicle Category	Test result according to method A [dB(A)]				
	Number	Mean	Minimum	Maximum	Median
M1	655	72,1	66,6	75,0	72,1
M1G	24	73,3	70,0	76,0	73,0
M2	28	74,4	70,0	78,0	75,0
M3	76	77,8	73,0	81,7	78,0
N1	52	73,7	69,5	78,0	73,7
N1G	3	75,4	72,0	78,2	76,0
N2	55	76,3	72,0	79,7	77,0
N3	100	79,7	73,6	82,0	80,0
N3G	39	81,4	80,0	82,0	82,0
No data	3	71,0	69,0	74,0	
Total	1035	74,0	66,6	82,0	

Table 8 – Noise emission test results according to method B per vehicle category

Vehicle Category	Test result according to method B [dB(A)]				
	Number	Mean	Minimum	Maximum	Median
M1	656	70,0	64,0	80,9	69,9
M1G	24	71,0	67,0	75,0	70,8
M2	28	73,4	69,0	78,0	73,6
M3	76	77,1	71,9	82,6	77,6
N1	52	72,0	67,7	76,0	72,0
N1G	3	74,2	72,6	76,0	74,0
N2	55	75,0	70,0	79,5	75,0
N3	100	80,9	76,9	84,4	81,0
N3G	39	82,0	79,7	85,2	82,2
No data	3	70,3	67,0	75,0	
Total	1036	72,5	64,0	85,2	

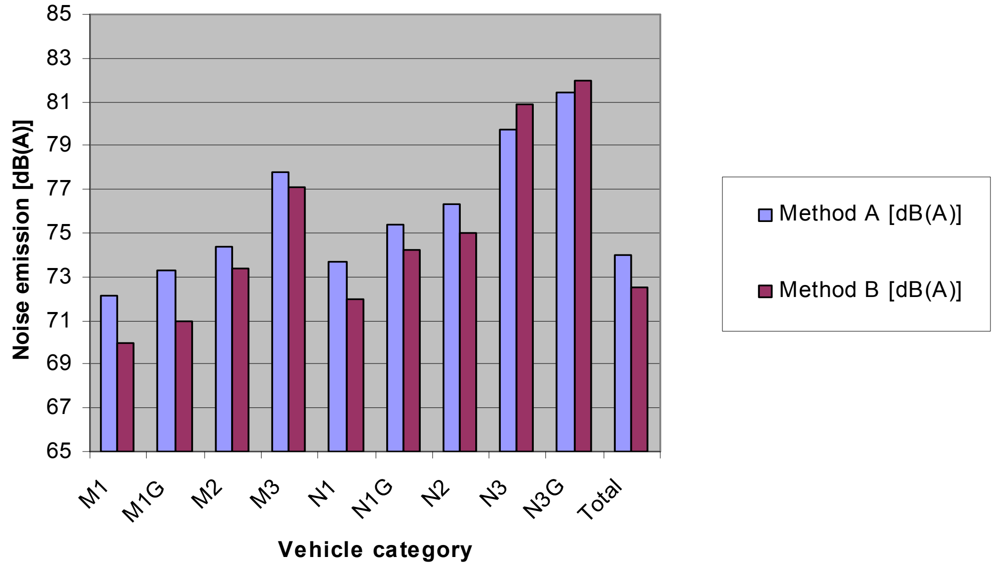


Figure 2 - Average test results of methods A and B per vehicle category

Table 9 – Difference between noise emission test results according to method B and to method A per vehicle category

Vehicle Category	Difference of test results: method B – method A [dB(A)]				
	Number	Mean	Minimum	Maximum	Median
M1	653	-2,1	-6,9	10,7	-2,0
M1G	24	-2,3	-8,4	1,9	-2,0
M2	28	-1,0	-5,7	5,0	-1,0
M3	76	-0,7	-4,9	3,6	-0,9
N1	52	-1,7	-5,2	4,7	-1,9
N1G	3	-1,2	-2,2	0,6	-2,0
N2	55	-1,2	-5,5	3,0	-1,6
N3	100	+1,2	-2,8	8,3	+1,3
N3G	39	+0,6	-2,1	3,6	+0,7
No data	3	-0,7	-3,0	1,0	
Total	1033	-1,5	-8,4	10,7	

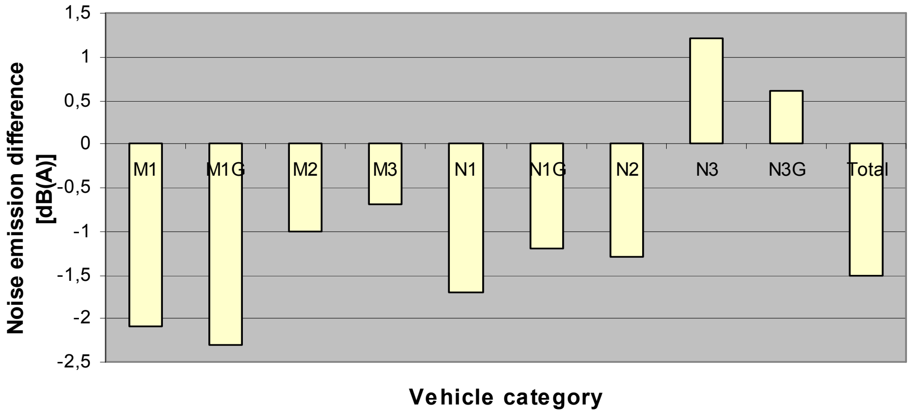


Figure 3 - Average difference between the test results of methods B and A per vehicle category

5.2.2 *Noise emission test results as a function of vehicle and powertrain characteristics*

For the evaluation of the current allowances and for the definition of possible future categories within the revised limit value system, it was considered how some main vehicle and powertrain characteristics relate to the results of both test methods and to the difference between the two. The following characteristics were studied:

- Engine type: Petrol (= Positive Ignition = Spark Ignition) or Diesel (=Compression Ignition);
- Gear box type: manual or automatic transmission or CVT

In Table 10 the test results according to methods A and B per vehicle category are given as a function of the above mentioned characteristics. In
Table 11 and Table 12 the influence of the engine type is given per vehicle category and per type approval limit value for test results A and B. The consequences of these findings is discussed in 5.4 and 6.2.2

Table 10 – Test results of methods A and B per vehicle category as a function of the engine type and the gearbox type

Vehicle Category	Test results method A [dB(A)]		Test results method B [dB(A)]		Test results method A [dB(A)]			Test results method B [dB(A)]		
	Engine type		Engine type		Gearbox type			Gearbox type		
	Petrol	Diesel	Petrol	Diesel	Manual	Automatic	CVT	Manual	Automatic	CVT
M1	72,3	71,7	70,3	69,6	72,4	71,4	69,9	69,9	70,3	69,2
M1G	72,1	73,9	70,9	71,1	74,7	72,1		70,5	71,4	
M2	72,0	74,5	72,0	73,4	74,7	73,2		72,7	75,9	
M3	77,1	77,9	76,8	77,2	78,9	77,3	81,0	77,3	77,0	76,6
N1	73,0	73,9	71,2	72,2	74,1	72,3		71,8	72,9	
N1G		75,4		74,2	77,1	72,0		75,0	72,6	
N2		76,3		75,0	77,0	73,6		75,4	73,8	
N3		79,7		80,9	80,0	79,5		80,4	81,2	
N3G		81,4		82,0	81,4	81,3		81,8	83,1	

Table 11 – Test results of method A per vehicle category as a function of limit value and engine type

Limit value	Engine type	M1		M1G		M2		M3		N1		N1G		N2		N3		N3G	
		Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)	Nr.	test A dB(A)
74	Petrol	297	72,1	2	73,0														
	Diesel																		
75	Petrol	64	73,5	6	71,8														
	Diesel	259	71,8	6	73,8	4	71,3			16	72,9	1	72,0	1	72,0				
76	Petrol									3	73,8								
	Diesel			7	74,4					2	73,0	1	76,0						
77	Petrol					1	72,0			6	72,6								
	Diesel			3	72,7			1	77,0	3	73,6								
78	Petrol																		
	Diesel					19	74,5	8	75,8	20	74,7			36	75,6				
79	Petrol																		
	Diesel					4	77,5	2	77,5	2	77,5	1	78,2	4	76,4				
80	Petrol							6	77,1										
	Diesel							59	78,2					14	78,3	100	79,7	2	80,0
82	Petrol																		
	Diesel																	37	81,5
Total		620	72,1	24	73,3	28	74,4	76	77,8	52	73,7	3	75,4	55	76,3	100	79,7	39	81,4

Table 12 – Test results of method B per vehicle category as a function of limit value and engine type

Limit value	Engine type	M1		M1G		M2		M3		N1		N1G		N2		N3		N3G	
		Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)	Nr.	test B dB(A)
74	Petrol	300	70,2	2	71,0														
	Diesel																		
75	Petrol	64	70,9	6	70,8														
	Diesel	258	69,7	6	70,5	4	70,5			16	71,3	1	72,6	1	72,0				
76	Petrol									3	70,7								
	Diesel			7	70,8					2	73,9	1	74,0						
77	Petrol					1	72,0			6	71,4								
	Diesel			3	72,8			1	80,6	3	70,9								
78	Petrol																		
	Diesel					19	73,9	8	75,5	20	72,8			36	74,0				
79	Petrol																		
	Diesel					4	73,9	2	75,0	2	74,3	1	76,0	4	75,5				
80	Petrol							6	76,8										
	Diesel							59	77,4					14	77,8	100	80,9	2	81,6
82	Petrol																		
	Diesel																	37	82,0
Total		622	70,0	24	71,0	28	73,4	76	77,1	52	72,0	3	74,2	55	75,0	100	80,9	39	82,0

5.3 Interpretation of the results of the data analysis

The results of noise emission tests A and B in Table 7, Table 8 and Table 9 show that for the small and medium-sized vehicles (M1, M1G, M2, N1, N2) and for the full size buses (M3) the results of test method B are significantly lower than the results of test method A. The shift in the average results is between – 0,7 and – 2,3 dB(A). For passenger cars the change of the average of the test values is -2,1 dB(A). The range of the test values for method B is considerably larger than for method A. E.g. for passenger cars the upper limit for method A values is 74 or 75 dB(A), depending on the current limit values (see Table 8), while for method B values, the spread above the mean value is much larger, upto an upper limit of 80,9 dB(A). Upon further examination of the cars with the highest results in the data files it can be noticed that there are only 19 passenger cars that give results of 75 dB(A) and above. Eight of these ten vehicles are very high-powered cars with maximum engine powers between 208 and 386 kW; one is a high-powered small car with 155 kW and one is a normal midsized car with 80 kW. The reason for the high test results of method B might be that for these high-powered cars the adaptation of the noise emission to the conditions of test method A is not effective in the case of test method B and that therefore these cars produce a significantly higher sound emission in test B than in test A. Four of these eight cars are strongly out of line with the normal spread of results (see also Figure 7), so these four should probably not be considered as representative members of the population. However, the overall picture for passenger cars, small en medium-sized vehicles and full size buses is that the test results of method B are lower than those of method A. The full size buses of category M3 exhibit the smallest downward change of -0,7 dB(A).

The situation is different for the heavy vehicles of categories N3 and N3G. For category N3, 82 of the 100 vehicles show equal or higher results for test B than for test A. The average upward change is 1,2 dB(A), while the test B result of 66 of these vehicles exceeds the current limit value of 80 dB(A). For the off-road heavy vehicles of category N3G there is a smaller upward change of 0,6 dB(A), while 14 of these vehicles would exceed the current limit value of 82 dB(A) with its method B result.

5.4 Relations between noise test results and vehicle and powertrain characteristics

In view of the research questions concerning the allowances to the limit values an extensive series of analyses was carried out to find correlations between specific vehicle and powertrain characteristics and the noise emission measured either with test method A or method B. The following characteristics were evaluated:

- vehicle category;
- current noise emission limit value
- engine type (Petrol or Diesel);
- gearbox type (manual or automatic);
- engine capacity;
- engine power;
- power to mass ratio (with the mass defined according to method A as well as method B).

5.4.1 Vehicle category

In nearly all analyses the vehicle category was used as the primary variable according to which the results were classified (see Table 7, Table 8 and Table 9). Although the ranges of the test results of the different categories show considerable overlap, the mean values of the noise emission measured according to both test methods are very well correlated to the vehicle category.

5.4.2 *Current noise emission limit value*

Within each vehicle category a further division in sub-categories may be relevant, because the differentiations of the limit values are related to subdivisions of vehicle mass, engine type and engine power. Therefore the currently valid limit values were used as a secondary variable, because they are directly related to the subcategories. These limit values for each vehicle could be derived from the report sheet of the method A results in the database in which this value had to be specified by the submitting authority. Unfortunately we observed many cases in which the specified limit value was apparently not correct. The most obvious case of incorrectly specified limit values were a series of M1 vehicles with Diesel engines for which limit values of 74 dB(A) were mentioned. As it could be verified that all tested M1 vehicles with Diesel engines were equipped with a direct-injection Diesel engine, the proper limit value would be 75 dB(A), because an allowance of 1 dB(A) would be applicable. In these 52 cases the specified limit value was corrected before the analysis. Also some other obvious cases of incorrectly specified limit values were corrected: some N3G vehicles with a specified limit value of 83 dB(A) were corrected to 82, because a limit value of 83 does not exist. However, an integral verification and correction of the specified limit values of all vehicles was not carried out, because such an action was not part of the scope of the study. Nevertheless, the specified limit values were used as a category variable in an analysis of the results of tests A and B. It appeared that the relationship between the mean values of the noise emission and the applicable limit value was not completely logical and unequivocal, neither for test method A nor for method B. The relationship between the mean test results and the applicable limit value was less clear than the one between the mean test results and the vehicle categories. This may be considered as a clear sign that the basis for the limit values needs to be reconsidered. The results of this part of the analysis were not included in the report, because they do not constitute useful information for the purpose of this investigation.

5.4.3 *Engine type*

The distinction between Petrol and Diesel engines is very important in the current system of limit values, because of the allowance of 1 dB(A) for direct-injection Diesel engines (see sub-section 6.2.2.2.1. of Regulation 51 [2]). From Table 10, Table 11 and Table 12 it can be inferred that for passenger cars (M1 vehicles) the basis for this allowance no longer exists. Both for test method A and B the average test result of the Diesel engines is lower than the result of the Petrol engines. For the off-road M1G vehicles the Diesel engines show a higher average noise emission than the Petrol engines according to method A but the difference according to method B is negligible. Moreover, the total number of vehicles in this category is small compared to the number of M1 vehicles. As most of the engines of category M1G vehicles are in a technical sense similar to the engines used in M1 vehicles, it seems logical to conclude that also for the M1G vehicles there is not a firm basis for an allowance based on the engine type.

According to sub-section 6.2.2.2.1. the 1 dB(A) allowance for direct-injected Diesel engines is not only valid for M1 vehicles but also for N1 and M2 vehicles with a mass not exceeding 3,5 tons.

For the N1 vehicles, the mean values for test A and test B results for Diesel engines are 0,9 resp. 1,0 dB(A) higher than for Spark Ignition (= Petrol) engines. The number of Spark Ignition engines involved is 9 versus 43 Diesel engines. 5 of these 9 Spark Ignition engines are in fact modified Diesel engines adapted for the use of compressed natural gas, while the other 4 petrol engines are also used in passenger cars. Therefore the basis for the comparison is rather weak..

For the category M2 vehicles, only 1 test result for Petrol engines is available in the database, so for this category no reliable comparison of the influence of engine types can be made.

5.4.4 *Gearbox type*

From the first analysis results it appeared that the type of gearbox (manual or automatic) had a significant influence on the overall average over the vehicle categories of the differences between the results of test A and test B. The results for the Continuously Variable Transmission (CVT), of which only 7 specimens were present in the database, were rather close to the results of the automatic transmissions. Therefore a further analysis of the influence of the gearbox type was carried out. In Table 10 the effect of the gearbox type on the results of test A and test B is presented per vehicle category. From this table it may be inferred that for all vehicle categories the results of test A are lower for automatic and CVT than for manual gearboxes. However, for the results of test B the situation is the opposite, except for category N2 and M1 with CVT: automatics give a higher average noise emission than manual gearboxes. It seems likely that this change is caused by the change in testing instructions: according to test A automatics shall be tested in the normal (= automatic) position of the gear selector, as long as no downshift to the lowest gear occurs. According to test B automatics shall be tested in a specific gear, if the gear ratio can be locked. Apparently the specific influence of the gearbox type is caused by this change in procedure, and not by any factor related to vehicle technology or to acoustical mechanisms.

5.4.5 *Engine cylinder capacity - Engine power – Power to mass ratio*

In both test methods, the most dominant operational parameter for the noise emission is the acceleration that can be achieved at a speed of 50 km/h in a prescribed gear ratio. This parameter is directly related to engine parameters such as: engine cylinder capacity, engine power or power to mass ratio (PMR) of the vehicle. Therefore the correlation of the noise emissions measured according to both test methods with these 3 parameters was investigated.

When all vehicle categories in the database were added together it appeared that a good correlation could be found between the noise emission test results and the logarithm of the engine capacity (correlation coefficient test A = 0,75; test B = 0,79). The correlations with the engine power and the power to mass ratio were less convincing (correlation coefficients between 0,24 and 0,62).
When, however, the correlation analysis was carried out for separate vehicle categories, the correlation coefficients dropped to much lower values (0,41 – 0,50 for a 3 parameter multiple regression) and the correlations of noise emission with the 3 parameters were not significant.
It seems remarkable that in particular the PMR does not show a very distinct correlation with the noise emission. As the PMR is the most important parameter that determines

the achievable acceleration of a vehicle one would expect that this parameter would show a high correlation with the noise emission. For this reason, the target acceleration and reference acceleration in method B are directly related to the PMR. However, in test method B the influence of the PMR is compensated largely by the fact that the test is to be executed in higher gears if the PMR of the vehicle and the achievable acceleration are high. This reduces the achieved engine speed and the noise emission during the test. Also in test method A there is a compensation for the influence of the PMR for high-powered cars: if a car fulfils the criteria for the extra allowance for high-powered cars (see 6.2.4), it is to be tested in third gear only instead of in second and third gear. This part of the test procedure results in lower measured noise emissions for cars with a high PMR.

6 Elaboration of policy options

6.1 General approach

In the policy options 1 and 2, no change of limit values compared to the currently valid limit values is asked for. In the policy options 3, 4 and 5 new limit values have to be proposed according to different criteria. The values proposed for these options have been derived from the database firstly by comparing the average results of test A and test B. Secondly, the outcome of a regression analysis of the results of test B as a function of the results of test A per vehicle category was used to estimate the required shift of the limit values to achieve a set of requirements that would be equivalent to the current type approval requirements. Thirdly, an analysis was made of the percentage of vehicles per category for which the test B result would not comply with the limit values if these were set at different levels. The results of this analysis were gathered in non-compliance tables (see Appendix D)

Finally the distributions of the test values per vehicle category as a function of the test A and test B results (in 1 dB steps) were compared in order to estimate to what extent the adaptation of the vehicles to the test set-up may influence the spread of the results; see Figure 9, Figure 10 and Figure 11. Also the non-compliance percentage of the test results with the currently applicable limit value for the vehicle in question was considered. The currently applicable limit values were derived from the database files (in some cases after correction – see 5.4.2). For nearly all vehicles the results of test A were equal to or below the applicable limit value. Only in 11 cases (1%) the limit values were exceeded by 1 or 2 dB(A).

However, the results of test B exceeded the currently applicable limit value for the vehicle in question in 103 cases (10 %). The limit values were exceeded by 1 upto 7 dB(A).

As discussed in 5.3 from the fact that hardly any test A result exceeds the current limit values it can be infered that the tested vehicles always are tuned to the test conditions so as to pass the type approval test without difficulty. The result of this is that the distribution of the test results exhibits an asymmetrical shape: there is a cut-off at the high values, which can be seen clearly in the distribution for the M1 vehicles (Figure 9.a). Such a cut-off is not present in the distributions of the test B results. The difference between the distributions was used to estimate the effect of optimisation of the vehicles to the test conditions.

6.2 Relevance and justification of special allowances

6.2.1 General considerations on the applied methodology

In this section the relevance and justification of the currently valid extra allowances for special sub-categories of vehicles (according to sub-section 6.2.2.2 of UNECE Regulation 51 References [2]) are discussed. The findings and conclusions are based on an analysis of the vehicle data files in the CIRCA database. This approach, however, suffers from a fundamental shortcoming. The analysis only deals with vehicles that were developed under the currently valid system of special allowances. Therefore the developers of these vehicles are likely to have used the extra margin for noise emission offered by the allowances. As a consequence of this the analysis of the available data can only deliver a proof that there is no need for a specific allowance, but not a proof that an allowance is necessary.

If there is no significant difference in noise emission between vehicles that fulfil the conditions for an allowance and vehicles that do not, one can conclude that this specific allowance is not justified. If however the data show that there is a significant difference, it only indicates that the designers have used the extra margin, but not that this extra margin was essential for the design of the vehicles in question nor that it would be very difficult or costly to achieve a (slightly) lower noise emission.
As no other data were available than the data of the vehicles recently introduced on the market, there was no means to avoid this shortcoming. The reader should be aware of this when interpreting the conclusions discussed in the following sub-sections.

6.2.2 *Allowance of 1 dB(A) for direct-injection Diesel engines*

According to sub-section 6.2.2.2.1 of Regulation 51 [2] an allowance of 1 dB(A) for "vehicles equipped with a compression-ignition and direct-injection internal combustion engine" shall be applied for vehicle types mentioned in the sub-sections 6.2.2.1.1. and 6.2.2.1.3. This incorporates the vehicle categories M1, N1 and M2 with a mass not exceeding 3,5 tonnes. As discussed in 5.4.3 this allowance appears no longer to be relevant or justified.

The allowance was introduced in 1996 when direct-injection Diesel engines were introduced in passenger cars and smaller commercial vehicles and they appeared to have a higher noise emission than the pre-combustion Diesel engines used until then.
In the database of vehicles tested in the period from July 2007 until July 2010, all Diesel engines were of the direct-injection type, so the reason for a distinction between pre-combustion Diesel engines and direct-injection Diesel engines no longer exists.
Moreover, for the vehicles of category M1, it appeared that the average noise emission of the Diesel engines was lower than the average noise emission of the Petrol engines, as well for test A as for test B results. Therefore an allowance for Diesel engines relative to Petrol engines is no longer justified for M1 vehicles.
For M1G vehicles the average test result according to test A is 1,8 dB(A) higher for Diesel engines than for Petrol engines, but according to test B it is only 0,2 dB(A) higher, which is not a significant difference. Most of the engines of category M1G vehicles are in a technical sense similar to the engines used in M1 vehicles.
Therefore, it is concluded that for a future system of limit values based on the new test method B there is no justification for M1G vehicles for an allowance for Diesel engines relative to Petrol engines.
For N1 vehicles and M2 vehicles with a mass not exceeding 3,5 tonnes only a limited number of vehicles (9 and 1 respectively) with Spark Ignition engines was available in the database. This indicates that Spark Ignition engines are rather uncommon in these vehicle categories. Moreover, 5 of the Spark Ignition engines are in fact converted Diesel engines and the other 5 are also used as passenger car engines. Therefore the comparison between Spark Ignition and Diesel engines for these vehicle categories is not well founded. It can be concluded that the relevance of an allowance for Diesel engines in these categories cannot be shown in a convincing manner. Also for the sake of simplification it is considered preferable to delete the allowance for direct-injection Diesel engines completely from the future system of limit values.

6.2.3 *Allowance of 1 or 2 dB(A) for vehicles designed for off-road use*

According to sub-section 6.2.2.2.2. of Regulation 51 [2] an allowance of 1 dB(A) shall be applied for vehicle types designed for off-road use with a maximum authorised mass above 2 tonnes and an engine power of less than 150 kW. If the engine power is 150 kW or above the allowance shall be 2 dB(A).
In the database there are 2 categories of vehicles for which a comparison can be made between vehicles with off-road capabilities and normal vehicles:

- Passenger cars M1 vs. SUV's and Four-wheel Drives M1G;
- Heavy trucks N3 vs. off-road trucks N3G.

Table 7 and Table 8 show the average noise emission according to test methods A and B.
For M1 – M1G the increase in noise emission according to A resp. B is 1,2 resp. 1,0 dB(A).
For N1 – N1G the increase in noise emission according to A resp. B is 1,7 resp. 2,2 dB(A), but the number of N1G vehicles in the database is only 3, which is too small to be the basis for any conclusion.
For N3 – N3G the increase in noise emission according to A resp. B is 1,7 resp. 1,1 dB(A).
In the cases of the M1G and the N3G vehicles there appears to be a basis for an allowance of 1 dB(A) in the future system. The justification of the current distinction for vehicles with an engine power below and above 150 kW cannot be demonstrated for M1G vehicles. Also for the sake of simplification this distinction should be deleted.
For N3G vehicles with an engine power above 150 kW a 2 dB(A) higher limit value than for the corresponding N3 vehicles will be proposed in sub-section 6.3.3. This is not motivated by the difference between N3G and N3 vehicles, but by the differences in the results of test method A and B.

It is recommended to include off-road sub-categories for all vehicle categories, each with a 1 dB(A) higher limit value than the normal vehicles of the category, except for N3 vehicles, which should be assigned a 2 dB(A) higher limit value. This increase of the limit values should be restricted to vehicles that fulfil the off-road criteria according to Article A.4 of Annex II of EU Directive 2007/46/EC, with the restriction that limit values for M1 and N1 vehicles shall only be increased if the maximum authorised mass of the vehicle exceeds 2 tonnes.

6.2.4 *Allowance of 1 dB(A) for high-powered passenger cars*

According to sub-section 6.2.2.2.3. of Regulation 51 [2] an allowance of 1 dB(A) shall be applied for vehicle types of category M1 fitted with a gearbox having more than four forward gears and equipped with an engine developing a maximum power greater than 140 kW and having a maximum-power / maximum-mass ratio (PMR) greater than 75 kW/t, if the speed at which the vehicle passes the line BB' in third gear is greater than 61 km/h. If the vehicle fulfils these criteria also the test procedure according to method A is modified in the sense that the vehicle has to be tested only in third gear, while the normal procedure specifies an averaging of test results in second and third gear.

A number of 50 vehicles that fulfilled the three criteria mentioned above were selected from the database. The number of vehicles that fulfilled the criteria of maximum power above 140 kW and PMR above 75 kW/t was much larger (157), but only the 50 vehicles accelerated fast enough to attain a speed of more than 61 km/h at the line BB'.

According to test method A, the average of this subcategory was 1,7 dB(A) higher than the average of the other M1 vehicles with petrol engines. As for these vehicles also the test method was modified, the difference between the high-powered cars and the normal ones is in fact considerably greater than the reported difference. The noise emission in second gear can be between 2 and 7 dB greater than the noise emission in third gear. This means that the noise level measured only in third gear will be on average at least 2 dB(A) lower than the average of the noise levels measured in second and third gear. The actual difference between the high-powered and the normal cars can thus be estimated at 3,7 dB(A).

The results for test method B show a smaller difference of 0,8 dB(A). In method B the acceleration to be achieved during the test is dependent on the power to mass ratio of the vehicle. The choice of the gear is related to the acceleration to be achieved: one has to use the gear or gears that result in an acceleration as close as possible to the prescribed acceleration. For high-powered cars this leads to the use of relatively high gears in comparison to other cars. Consequently, also in method B, the noise emission test of high-powered cars is performed at lower engine speeds than for other cars and with subsequently lower noise emission values.

Based on the value of 0,8 dB(A) for the difference between the average noise emission of high-powered and of normal cars, an allowance of 1 dB(A) for this subcategory seems to be justified. A further analysis of the data showed that within the group of vehicles that fulfil the three criteria for high-powered cars there is only a very weak correlation between the PMR (power to mass ratio) and the test results of test A or test B (see Figure 4 and Figure 5). In Figure 6, the correlation between the results of test method B and test method A for high-powered cars is shown together with the regression line that is found for all M1 vehicles (see also Figure 7.a). Also for this, the correlation is low. It appears that the regression line for high-powered cars is not significantly different than the one for all M1 vehicles.

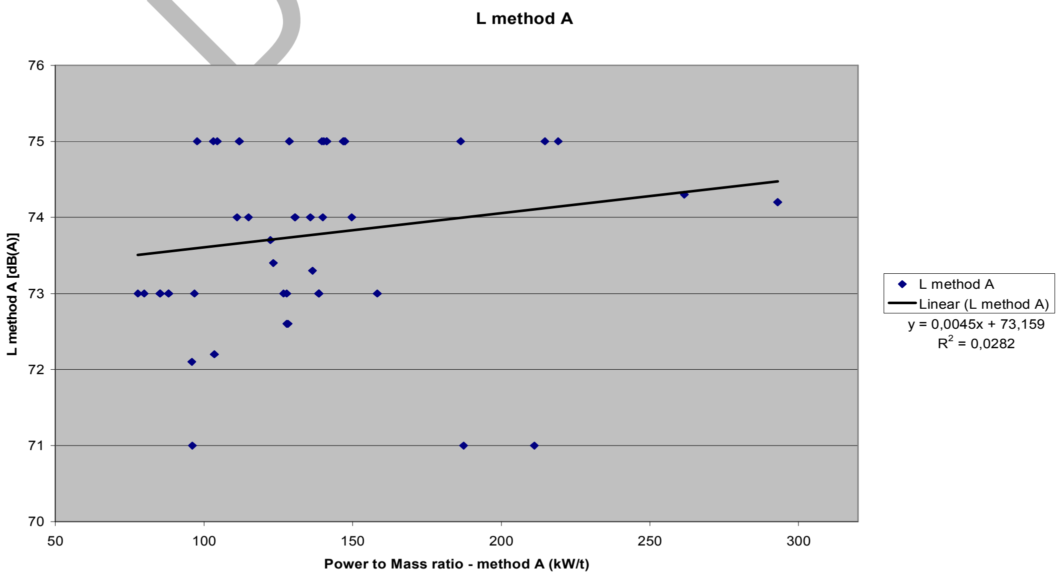


Figure 4 - Noise emission test results according to method A for high-powered cars as a function of the PMR (power to mass ratio) determined according to method A.

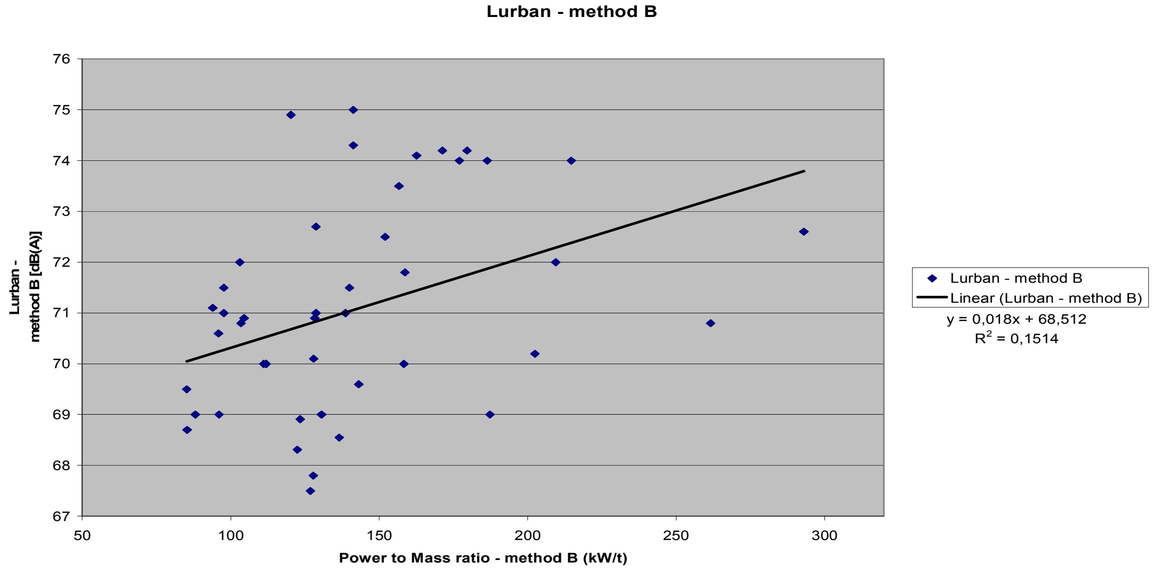


Figure 5 - Noise emission test results according to method B for high-powered cars as a function of the PMR (power to mass ratio) determined according to method B.

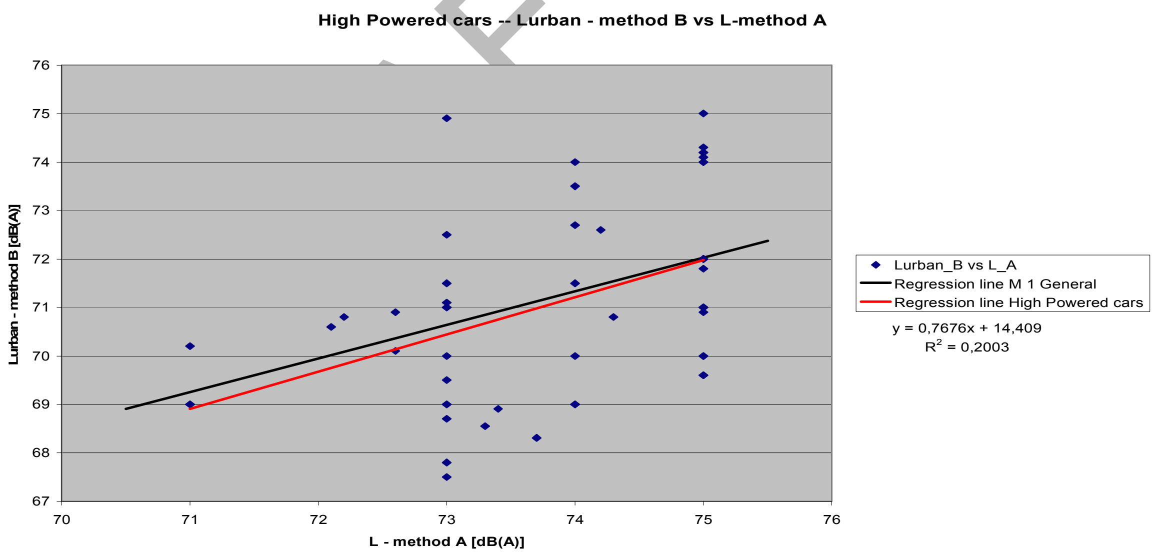


Figure 6 - Test results according to test method B as a function of the results according to test method A for high-powered cars

It is recommended to maintain an extra allowance of 1 dB(A) for high-powered cars in the future system of limit values. As the number of vehicle types on the market with an engine power above 140 kW and a PMR above 75 kW/t is gradually increasing it is recommended to revise the criteria for the extra allowance for high-powered cars. Otherwise the extra allowance could become applicable to a much larger group of vehicle types than was originally intended. Originally the allowance was meant as a compensation for a small number of sports car types with powerful engines that had a high acceleration capability, and that could not fulfil the noise emission requirements without a major technical design change of the vehicle. In order to limit the extra allowance to vehicles that may be considered as high-powered sports cars according to today's standards, the proposal is to revise the criteria. The main consideration for characterising high-powered cars should be the achievable acceleration, which is directly related to the power to mass ratio. Therefore a criterion for a minimum engine power is not necessary. Furthermore, if the limit to the achieved acceleration during the test of 2 m/s^2 is deleted, as proposed in Chapter 8, also criteria with respect to the acceleration achieved or the speed at the end of the test track are not necessary. Therefore the proposed criterion is very simple:

- Power to mass ratio greater than 150 kW/t

In test method B this criterion corresponds to a reference acceleration of 2 m/s^2, that has to be achieved during the WOT test. The current criterion for a minimum speed of 61 km/h at the end of the test track corresponds to a minimum acceleration of approximately 1,9 m/s^2, so the proposed PMR criterion will be slightly more selective. As the reference acceleration in test method B is independent of the type of transmission of the vehicle, no further requirements concerning the transmission of the vehicle are necessary.

6.2.5 *Accumulation of allowances*

In principle, more than one of the allowances discussed above can apply to a specific vehicle. The combination of a direct-injection Diesel engine with off-road capabilities is fairly common. Also the combination of off-road capabilities with a high power engine is feasible. Due to the small number of vehicles subject to these combined allowances no reliable analysis for the comparison of these sub-sub-categories could be made. Therefore in the results discussed above, the combination of factors that leads to the application of more than one allowance is already incorporated. This implies that there is no justification for the accumulation of allowances. Also for the sake of simplicity, accumulation of allowances should not be applied.

6.2.6 *Transformation of allowances to limit values*

The current formulation of the noise emission requirements within the framework of the vehicle type approval is a combination of limit values for vehicle categories and sub-categories and extra allowances for vehicles within those (sub)-categories that meet specific criteria. This type of formulation is ambiguous, because the definition of some sub-categories supersedes the formal definitions of vehicle categories and because the applicability of allowances and the accumulation of allowances is not completely clear.

It has been observed that in the database files many errors have been made with respect to the specified limit value for the vehicle in question. This indicates that the current system of 8 different basic vehicle (sub)- categories with several allowances that introduce additional sub-categories is too complex to be handled in an easy and reliable manner. Apparently even the type approval authorities who submitted the files cannot handle the system without a significant number of errors. Therefore a simplification of the system is strongly advised; this basic principle has been used in the elaboration of the policy options.

In Table 13 the basic limit values per vehicle subcategory and the allowances according to the current regulations are incorporated in one table that illustrates the large number of variants and the complexity of the system. For the various policy options other than option 1 (the current situation) the allowances are deleted except for the passenger cars

with a high power engine and for the M1, N1 and N3 vehicles with off-road capabilities.
It is recommended to consider vehicles with an allowance as a separate sub-category in the future limit value system.

The recommended form of the table of limit values and allowances for the recommended policy option is presented in Chapter 10.

Table 13 - Overview of the proposed limit values for the different policy option

Section (Reg. 51; Addendum 50; Rev 1)	Vehicle category	Description	Extra allowance option				Number of vehicles in data-base	Limit value Option 1	Limit value Option 2	Limit value Option 3	Limit value Option 4	Limit value Option 5	
			6.2.2.2.1	6.2.2.2.3	6.2.2.2.2.1	6.2.2.2.2.2							
			Direct-injection Diesel engine	High powered cars	Off-road; mass > 2 tonnes; rated power < 150 kW	Off-road; mass > 2 tonnes; rated power > 150 kW						First step	Second step
			1 dB(A)	1 dB(A)	1 dB(A)	2 dB(A)							
6.2.2.1.1	M1	Vehicles used for the carriage of passengers; no of seats ≤ 9					332	74	74	72	69	70	68
6.2.2.1.1	M1	Vehicles used for the carriage of passengers; no of seats ≤ 9	X				269	75	~~75~~	~~72~~			
6.2.2.1.1	M1	Vehicles used for the carriage of passengers; no of seats ≤ 9		X			51	75	75	73	70	71	69
6.2.2.1.1	M1G	Vehicles used for the carriage of passengers; no of seats ≤ 9			X		12	75	75	73	70	71	69
6.2.2.1.1	M1G	Vehicles used for the carriage of passengers; no of seats ≤ 9				X		76	~~76~~	~~73~~			
6.2.2.1.1	M1G	Vehicles used for the carriage of passengers; no of seats ≤ 9	X		X		7	76	~~76~~	~~73~~			
6.2.2.1.1	M1G	Vehicles used for the carriage of passengers; no of seats ≤ 9	X			X	3	77	~~77~~	~~74~~			
6.2.2.1.3.1	M2	Vehicles used for the carriage of passengers; no of seats > 9; mass < 2 tonnes					4	76	76	74	71	72	70
6.2.2.1.3.2	M2	Vehicles used for the carriage of passengers; no of seats > 9; 2 tonnes < mass < 3,5 tonnes						77	77	74	71	72	70
6.2.2.1.3.1	M2	Vehicles used for the carriage of passengers; no of seats > 9; mass < 2 tonnes	X				1	77	~~77~~	~~74~~			
6.2.2.1.3.2	M2	Vehicles used for the carriage of passengers; no of seats > 9; 2 tonnes < mass < 3,5 tonnes	X				7	78	~~78~~	~~75~~			
6.2.2.1.2.1	M2	Vehicles used for the carriage of passengers; no of seats > 9; 3,5 tonnes < mass < 5 tonnes; rated power < 150 kW					12	78	78	75	72	73	71
6.2.2.1.2.2	M2	Vehicles used for the carriage of passengers; no of seats > 9; 3,5 tonnes < mass < 5 tonnes; rated power > 150 kW					4	80	80	76	73	74	72
6.2.2.1.2.1	M3	Vehicles used for the carriage of passengers; no of seats > 9; mass > 5 tonnes; rated power < 150 kW					11	78	78	77	74	75	73
6.2.2.1.2.2	M3	Vehicles used for the carriage of passengers; no of seats > 9; mass > 5 tonnes; rated power > 150 kW					64	80	80	79	76	77	75
6.2.2.1.3.1	N1	Vehicles used for the carriage of goods; mass < 2 tonnes					21	76	76	73	70	71	69
6.2.2.1.3.2	N1	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes					6	77	77	74	71	72	70
6.2.2.1.3.1	N1	Vehicles used for the carriage of goods; mass < 2 tonnes	X				3	77	~~77~~	~~73~~			
6.2.2.1.3.2	N1	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes	X				22	78	~~78~~	~~74~~			
6.2.2.1.3.2	N1G	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes			X		2	78	78	74	71	72	70
6.2.2.1.3.2	N1G	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes				X		79	~~79~~	~~74~~			
6.2.2.1.3.2	N1G	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes	X		X		1	79	~~79~~	~~73~~			
6.2.2.1.3.2	N1G	Vehicles used for the carriage of goods; 2 tonnes < mass < 3,5 tonnes	X			X		80	~~80~~	~~74~~			
6.2.2.1.4.1	N2	Vehicles used for the carriage of goods; 3,5 tonnes < mass ≤ 12 tonnes; rated engine power < 75 kW					1	77	77	75	73	74	72
6.2.2.1.4.2	N2	Vehicles used for the carriage of goods; 3,5 tonnes < mass < 12 tonnes; 75 < rated engine power < 150 kW					40	78	78	76	74	75	73
6.2.2.1.4.3	N2	Vehicles used for the carriage of goods; 3,5 tonnes < mass < 12 tonnes; rated engine power > 150 kW					14	80	80	78	76	77	75
6.2.2.1.4.2	N3	Vehicles used for the carriage of goods; mass > 12 tonnes; 75 < rated engine power < 150 kW						78	78	78	76	77	75
6.2.2.1.4.3	N3	Vehicles used for the carriage of goods; mass > 12 tonnes; rated engine power > 150 kW					100	80	80	81	79	80	78
6.2.2.1.4.2	N3G	Vehicles used for the carriage of goods; mass > 12 tonnes; 75 < rated engine power < 150 kW			X			79	79	79	77	78	76
6.2.2.1.4.3	N3G	Vehicles used for the carriage of goods; mass > 12 tonnes; rated engine power > 150 kW				X	39	82	82	83	81	82	80

6.3 Overview of the proposed policy options

In Table 13 the proposed limit values are given for all policy options. In the sections below an explanation and motivation of the choices is given per policy option.

6.3.1 Policy option 1 – No change

In this option the current limit values will remain valid, as well as the measurement method A. The table presents all limit values and the allowances in a slightly different way than the usual presentation in the EU Directive 70/157/EEC and the UN/ECE Regulation 51. The limit values are sorted according to the vehicle category following the official definitions from Directive 2007/46/EC Annex II [6]. All differentiations connected to the limit values and allowances are presented as sub-categories.

6.3.2 Policy option 2 – New method – old limit values

In this option the new measurement method B will be combined with the current set of limit values. The limit values are the same as in option 1. However, the considerations concerning the justification of allowances apply also in this case. Therefore it may be considered to modify and simplify the allowances as proposed in section 6.2. This would imply the deletion of the allowances for direct-injection Diesel engines and the reduction of the allowance for off-road usable vehicles to a single allowance of 1 dB(A). Only in the case of the off-road heavy trucks the current allowance of 2 dB(A) is maintained, because the results of test B for this vehicle category indicate the relevance of this allowance.

6.3.3 Policy option 3 – New method – new limit values equivalent to old ones

For option 3, the new limit values should be equivalent to the current ones, meaning that all vehicles that are currently type-approved should easily comply with the new limit values under the new test method. For the derivation of the proposed new limit values from the current ones three different assessment methods were used:

a. A linear regression equation which describes the result of test B as a function of the result of test A according to:

   result B = *a* + *s*.(result A) **(1)**

   In Table 14 the values of the intercept ***a*** and slope ***s*** are given for those vehicle categories for which the regression analysis rendered significant results (M1, M3, N1 and N2). The graphs that show the data on which the regression equations are based are given in Figure 7 and Figure 8. The estimated new limit values derived from the current limit values with the regression equation are also given in Table 14;
b. Using the difference between the average results of test method B and test method A (see Table 9);
c. Use of the non-compliance tables and graphs in Appendix D to assess the percentage of vehicles that would not fulfil the requirements if a certain limit values were to be used.

For the vehicle categories M1G, M2, N3 and N3G, the regression analysis did not produce significant results, as can be seen in the respective graphs. For these vehicle categories the derivation of the equivalent new limit values was made by using methods b and c.

Table 14 – Estimate of the equivalent limit values for method B based on the regression analysis of method B results as a function of method A results

	Regression line		Limit values for current method [dB(A)]						
Vehicle category	Intercept *a*	Slope *s*	74	75	76	77	78	79	80
			Estimated limit values for new method [dB(A)]						
M1	20,07	0,693	71,3	72,0					
M1G		Not signft							
M2		Not signft							
M3	23,66	0,687					77,2	77,9	78,6
N1	34,86	0,504		72,7	73,2	73,7	74,2	74,7	
N2	9,90	0,854				75,6	76,5	77,4	78,2
N3		Not signft							
N3G		Not signft							

Table 15 - Estimate of the equivalent limit values for method B based on the average difference between the results according to methods B and A

		Limit values acc. current method [dB(A)]							
Vehicle category	B - A mean	74	75	76	77	78	79	80	82
	[dB(A)]	Estimated limit values for new method [dB(A)]							
M1	-2,1	71,9	72,9						
M1G	-2,3	71,7	72,7	73,7	74,7				
M2	-1,0			75,0	76,0	77,0	78,0	79,0	
M3	-0,7					77,3	78,3	79,3	
N1	-1,7	72,3	73,3	74,3	75,3	76,3			
N1G	-1,2								
N2	-1,2				75,8	76,8	77,8	78,8	
N3	1,2					79,2	80,2	81,2	83,2
N3G	0,6					78,6	79,6	80,6	82,6

After the first estimation of the new limit values, the percentage of vehicles per category of which the test B result would not comply with the estimated limit value was assessed from the compliance tables in Appendix D. A percentage of non-compliance between 5 and 15 % was considered acceptable, because from the distributions of the test B and test A results it could be inferred that adaptation to the new test method will result in a cut-off of the higher test results. This will cause a shift of 10 – 15 % of the highest test results of method B to lower values. For example, from the comparison of Figure 9.a and b it is estimated that an adaptation to the conditions of test B may produce a cut-off of the high test results at 72 dB(A) for the M1 vehicles in general, and at 73 for the high-powered M1 vehicles. For the other vehicle categories similar assessments were made, using the graphs of the Figure 9, Figure 10 and Figure 11. For the heavy trucks (N3, N3G) this procedure results in proposed new limit values that are equal to the current limit values or 1 dB(A) higher.

6.3.4 *Policy option 4 – New method – new limit values with noise reduction potential*

According to the service request in Policy Option 4, new limit values should be proposed in combination with the new test method in such a way that a reduction of the authorised noise emissions per motor vehicle may be expected.
For the elaboration of the limit values in this option it is important to consider that for the small and medium-sized vehicles (M1, N1, M2 < 3,5t), the test result of method B is to a considerable extent determined by tyre-road noise. As discussed in more detail in section 8.5 the acceleration test result $L_{wot\ rep}$ is a mix of powertrain noise and tyre-road noise, while the constant speed test $L_{crs\ rep}$ is to a large extent dominated by tyre-road noise. The final test result L_{urban} is a weighted average of these two intermediate results and will therefore be strongly influenced by tyre-road noise.

The rolling noise emission of tyres is subjected to a separate EU Regulation No. 661/2009 [7]. This regulation implies that from 1 November 2012, stricter limit values for tyre rolling noise will be in force for new types of tyres and from 1 November 2013 for new types of vehicles. These new requirements will result in an (estimated) average reduction of 3,8 dB(A) of the limit values for car tyres and of approximately 3,3 dB(A) for the limit values for truck tyres. From 1 November 2016 the stricter limit values will apply to all new vehicles and all new tyres (see also Appendix E).

The spread of noise emission values in most tyre classes is approximately 5 to 6 dB(A) below the current limit values. The current average of the noise emission is in most cases approximately equal to or slightly higher than the future limit values. This means that the introduction of the stricter limit values will result in the cut-off of the upper half or more of the tyre populations. Assuming that in the long run, new tyre types with lower noise emission will be developed, a spread of approximately 5 dB below the future limit value will emerge. The average noise emission of tyres may then be 3,3 to 3,8 dB(A) lower than the current values.

In Appendix E a calculation is given that shows how the lower noise emission of tyres will influence the vehicle type approval test results. The test results (according to method B) will on average decrease with 1,2 to 1,9 dB(A). This figure only applies to the vehicles of small and medium size (categories M1, M1G, M2 < 3,5t, N1 and N1G), because only for these vehicle categories the constant speed test has to be carried out, so that data are available. The consequence of this will be that the relative contribution of the powertrain noise in the overall test results will increase. Therefore it is considered to be feasible to lower the limit values for these vehicle categories with 3 dB(A): approx.1,5 dB(A) to account for the already diminished tyre-road noise and another 1,5 dB(A) to be achieved by the reduction of powertrain noise.

For the heavy vehicles, for which no information about tyre-road noise contributions is available a different approach was followed. For these vehicles the histograms (Figures 3, 4 and 5) and the non-compliance tables in Appendix D were used to assess the feasibility of various levels of limit value reduction. For the vehicle categories M2 ≥ 3,5t and M3 a limit value reduction of 3 dB(A) was considered feasible; for the categoriesN2, N3 and N3G a limit value reduction of 2 dB(A) is proposed in view of the high percentage of the current vehicle types in these categories that would not comply with a 3 dB(A) lower limit value.

Time frame for introduction
The proposed reduction of the vehicle noise limit values aims to build on the reduction of tyre road noise, resulting from the introduction of stricter limit values for tyre rolling noise. The reduction of these limit values will come into force on 1 November 2012. Assuming an implementation period of 1 year for less noisy tyres to become available for new vehicles types the introduction of the reduced vehicle noise limit values might take effect from 1 January 2014.

In order to avoid the necessity to change the noise emission of existing types of vehicles, that have already been type approved, within a short period of time , it is proposed to put the reduced limit values into force according to the following schedule:
1 January 2014 – for Type Approval of new types of vehicles;
1 January 2016 – for First Registration of all new vehicles

6.3.5 Policy option 5 – New method – new limit values with noise reduction potential in two step approach
In comparison to Policy Option 4, in Policy Option 5, a more ambitious final target for noise reduction is pursued. For the short term, however, a less ambitious target is aimed for in a first step of limit value reduction. This step should be followed by a second step in a later stage that would reach the final goal.
For the small and medium-size vehicles (M1, M1G, N1, N1G, M2 < 3,5 t) and the full size busses (M2 ≥ 3,5t, M3) a first step reduction of 2 dB(A) is proposed, followed by a second step of another 2 dB(A). The first reduction step can be achieved within a short period of time, because the required reduction of the noise emission can be obtained largely by using new tyres that fulfil the reduced limit values for rolling noise of tyres that will come into force from 1 November 2012.
The second reduction step will also require reduction of powertrain noise, in order to fulfil the stricter limits. Looking at the distributions of the test B results in Figure 9, Figure 10 and Figure 11, it follows that for each vehicle category the proposed future limit values are situated in the lower half of the distribution of the current test results. This means that a number of current vehicles would be able to fulfil these future limit values. From an inspection of the contents of the Circa database it appears that the vehicles that fulfil the future limit values already now do not have special characteristics and can be considered as representative for the various (sub)-categories. Therefore the proposed stricter limit values of option 5 are considered to be feasible based on currently available technology.

For the heavy trucks (M3, M3G) a first step of 1 dB(A) and a second step of 2 dB(A) is proposed, again based on the narrow range of noise emission test values and the high percentage of non-compliant vehicles. For these vehicle categories the reduction of rolling noise due to the stricter limit values for tyres will not be significant for the test results. The argument that the current technology enables the compliance with the future limit values is also valid for these vehicles, so the proposed limit values are also considered feasible in this case.

Time frame for introduction
Also in option 5 the proposed first reduction step of the vehicle noise limit values aims to build on the reduction of tyre road noise resulting from the introduction of stricter limit values for tyre rolling noise. The reduction of these limit values will be in force

from 1 November 2012. However, a considerable number of tyres that are currently on the market, will be able to fulfil the future limit values for rolling noise.

As the first step of option 5 constitutes a smaller limit value reduction than the proposals of option 4 it is possible to carry out the necessary development work with tyres that are already available. Therefore the first step reduction can be introduced on 1 January 2013. The second step will require more development effort and a more drastic set of technical measures: this step can be introduced from 1 January 2015.

In order to avoid the necessity to change the noise emission of existing types of vehicles, that have already been type approved, within a short period of time , it is proposed to put the reduced limit values into force according to the following schedule:
1 January 2013 – Stage 1 of limit value reduction (values step 1) for Type Approval of new types of vehicles;
1 January 2015 – Stage 2 of limit value reduction (values step 2) for Type Approval of new types of vehicles;
1 January 2017 - Stage 3 of limit value reduction (values step 2) for First Registration of all new vehicles.

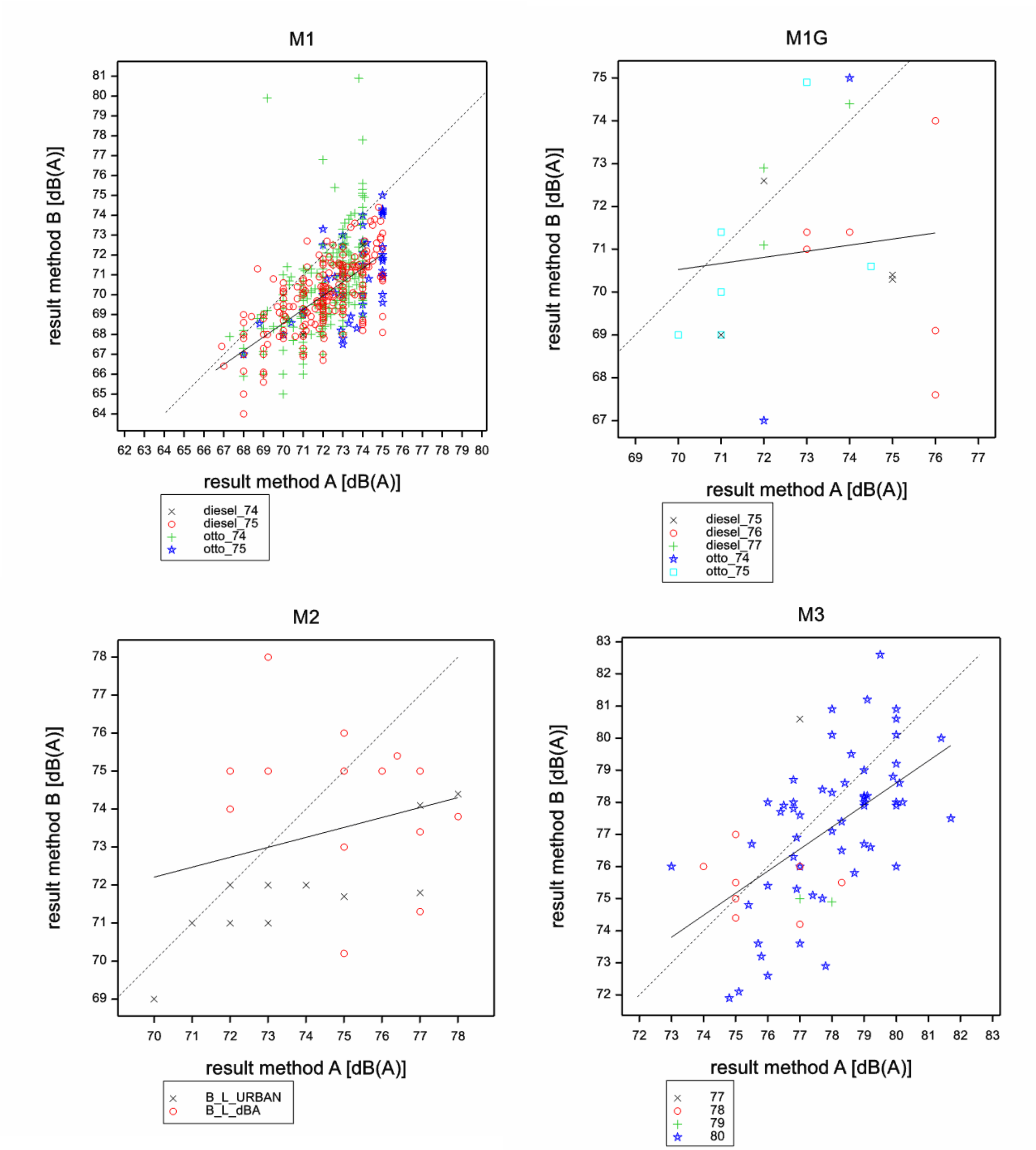


Figure 7.a-d – Graphs of the results of test method B presented as a function of the results of test method A for the vehicle categories M1, M1G and M3 (with limit values in colour code) and M2 (with results of different test method B variants in colour code).

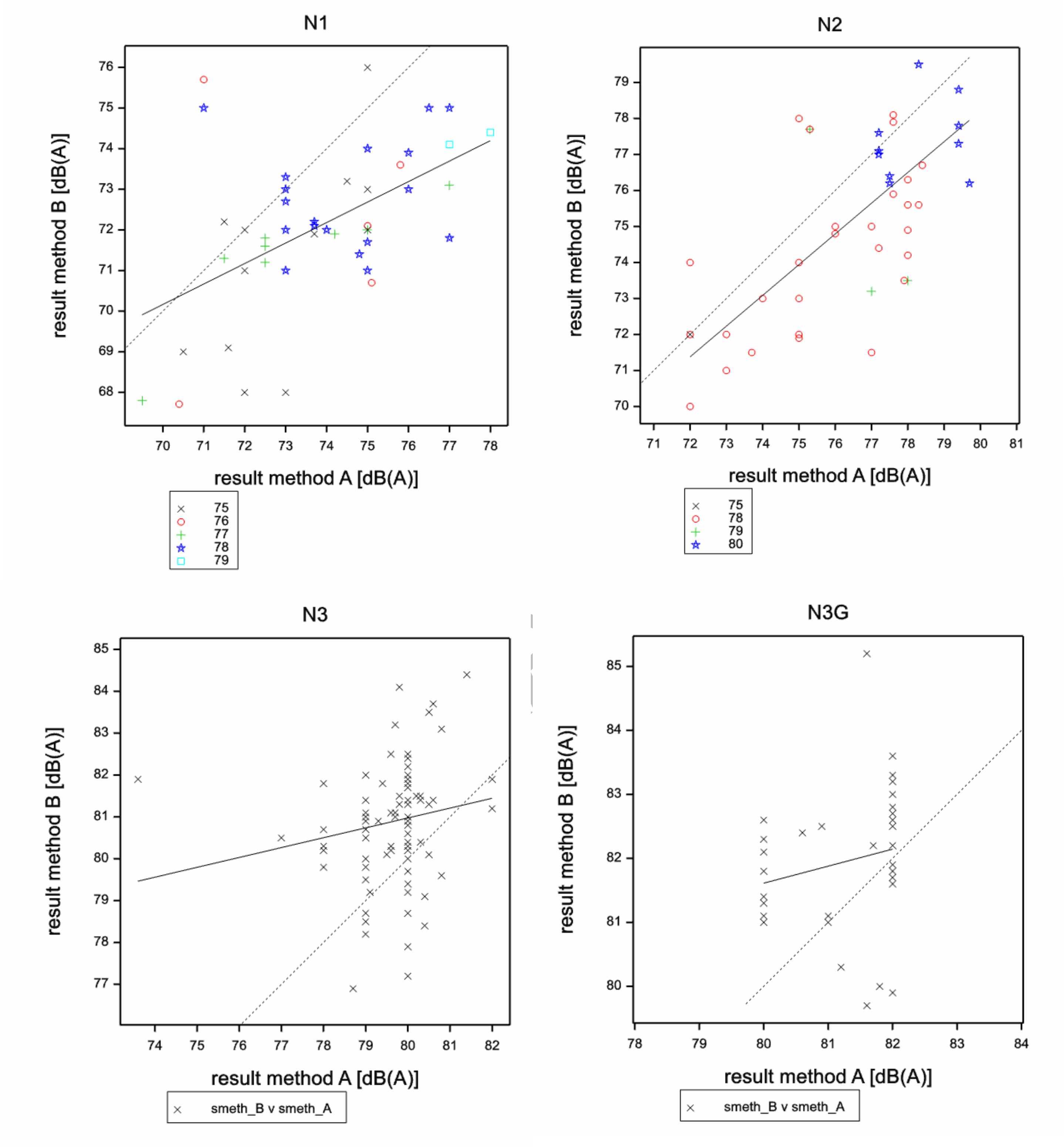


Figure 8a-d – Graphs of the results of test A presented as a function of the results of test B for the vehicle categories N1, N2 (with limit values in colour code) and N3 and N3G.

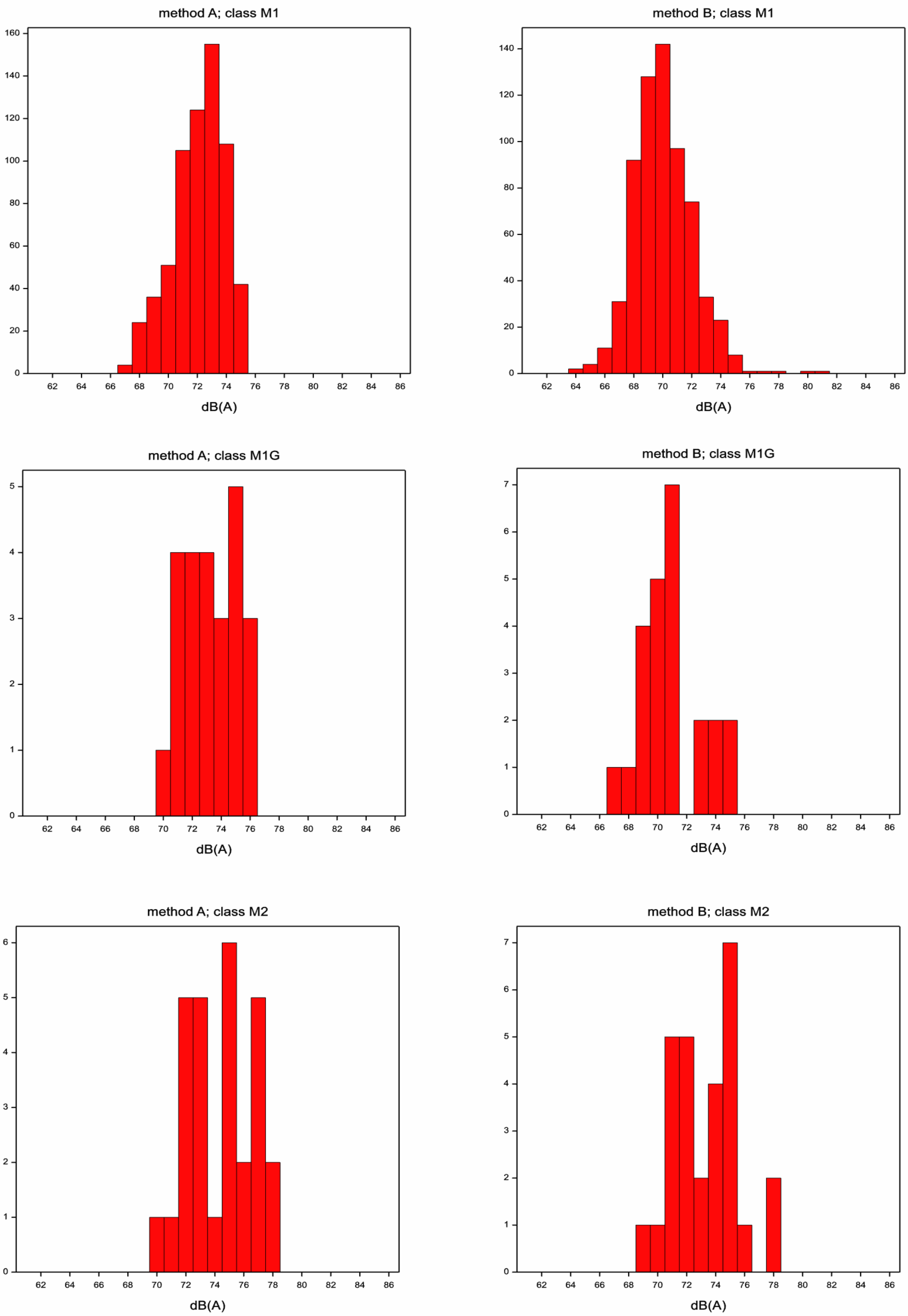


Figure 9.a-f – Histograms of the distribution of results of test A and B for vehicle categories M1, M1G, M2.

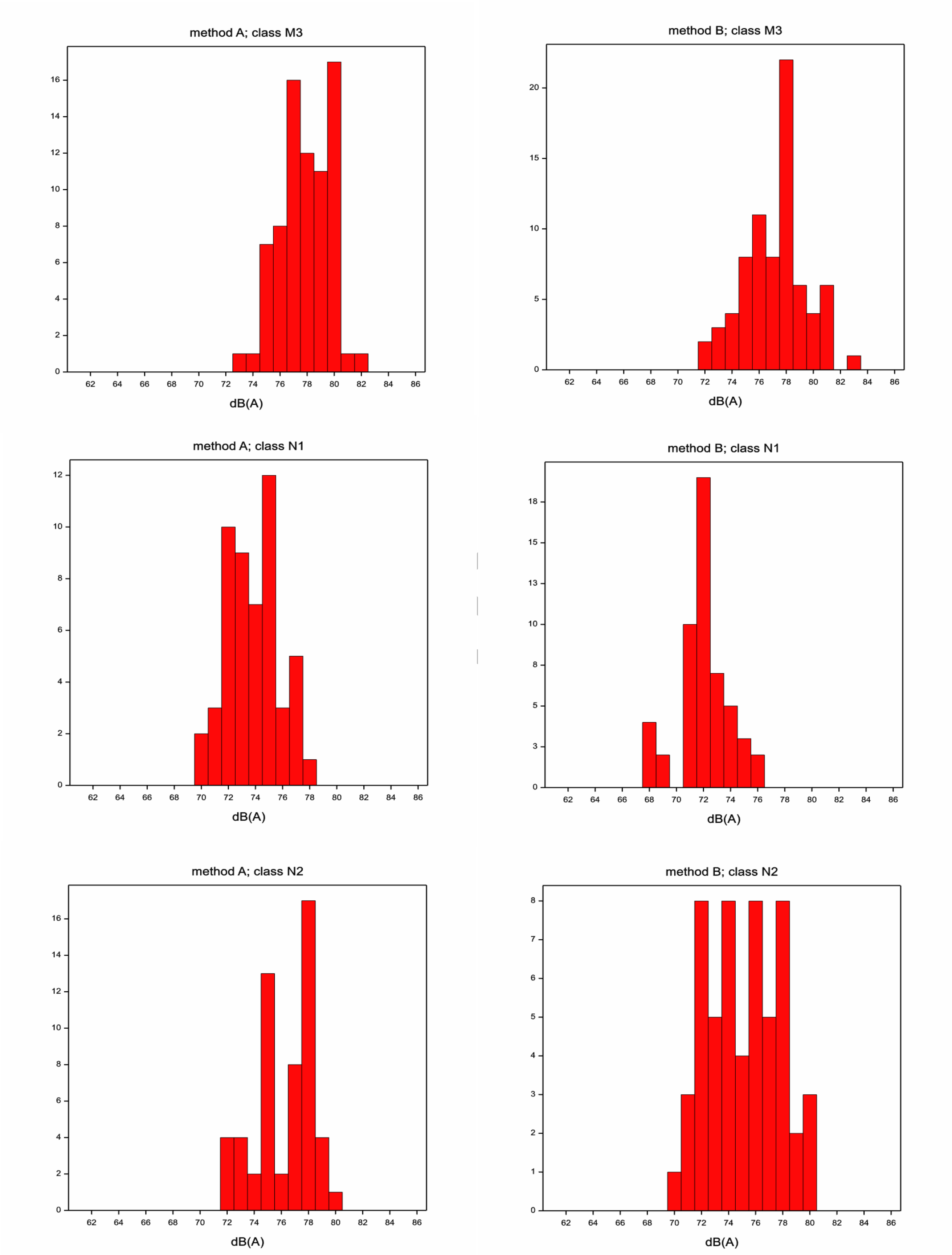


Figure 10.a-f – Histograms of the distribution of results of test A and B for vehicle categories M3, N1, N2.

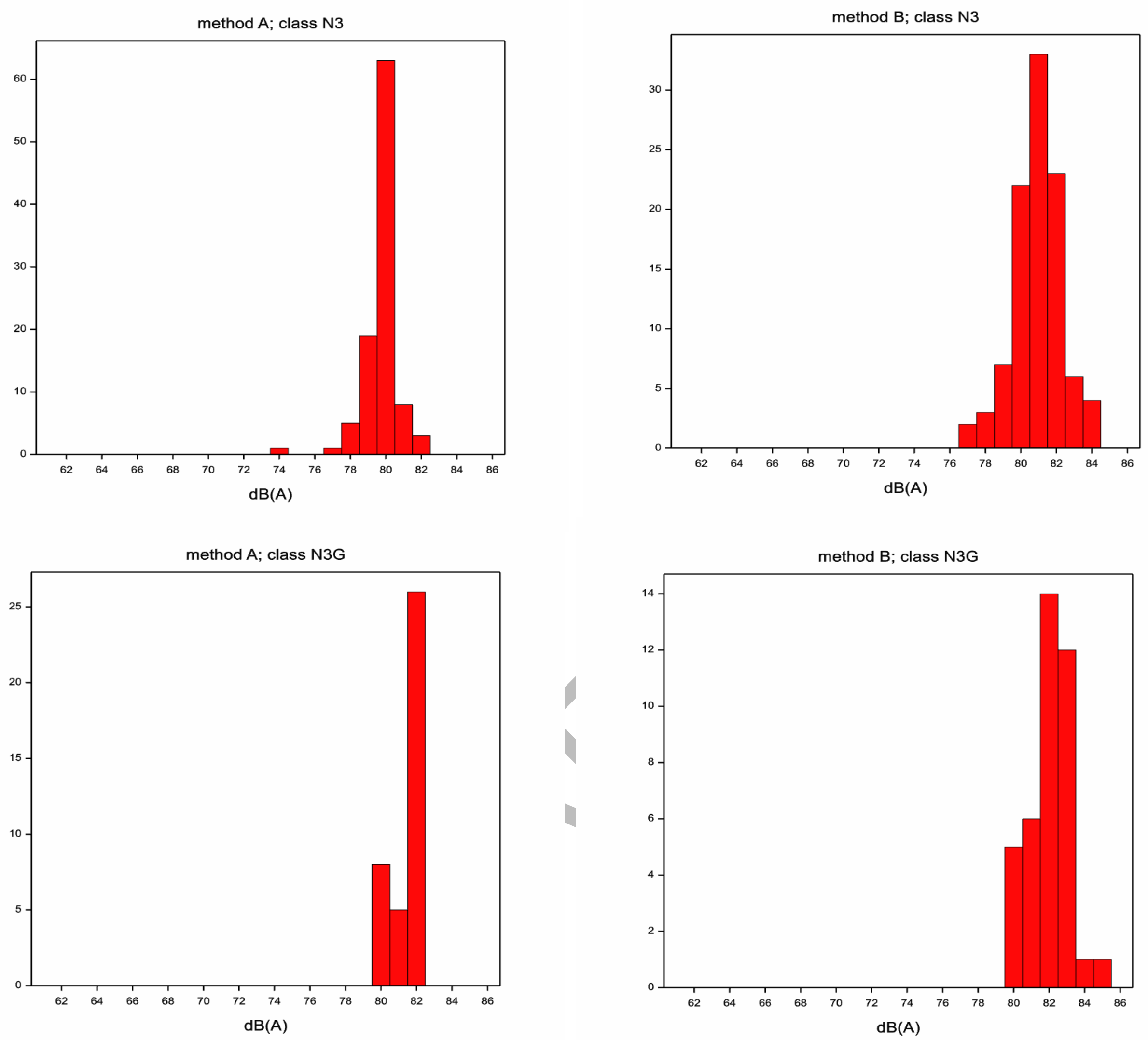


Figure 11.a-d – Histograms of the distribution of results of test A and B for vehicle categories N3 and N3G.

7 Impact assessments

7.1 Approach

This impact assessment covers the environmental, social and economic aspects of the five policy options. It is consistent with the EU Impact Assessment Guidelines (IAG) 2009 [35]. The analysis here takes the given five policy options as a starting point and covers the required IA parts 'Analysis of Impacts' and 'Comparing of Options'.

As the various impacts are not all quantifiable or lacking data, the impact assessment is first performed in a qualitative way. This is followed by a quantitative analysis of the main impacts where possible, based on available data, of each policy option. The environmental impact is defined in terms of reduction of L_{DEN}, L_{night} and single event levels. The social impact is described in terms of reduced annoyance, sleep disturbance, health effects, quality of life and reduced need for traffic noise abatement. The economic impacts and the cost benefit analysis are quantified based on estimates for the benefits to society and costs to industry, following guidelines on cost and benefit assessment where available and applicable.

The Directive and its original policy objectives are reviewed in section 7.2, followed by an overview of recent and current trends relevant to the Directive in section 7.3. The general impact of reducing vehicle noise levels is described in section 7.4. In section 7.5 the environmental impact is analysed for overall noise reductions and for the five policy options. The economic impacts and a cost-benefit analysis are covered in section 7.7. . The impacts are summarised in section 7.8.

7.2 Outline of the Directive and policy objectives

Directive 70/157/EC [1] and its amendments cover the requirements for motor vehicle exterior pass-by noise and the noise from the exhaust system under test conditions, covering the type testing procedure and noise limits. The original Directive and subsequent amendments have two objectives. Firstly, they aimed to ensure that for certain categories of motor vehicles, noise limits of individual states did not form barriers to trade. The second goal was to tighten the noise limits to reduce environmental noise. Although Member States were originally not bound to limits in the Directive, new trade barriers could not be created by stricter national limits. The amendment of 1992 (92/97/EEC) [8] introduced mandatory common noise limits applicable to Member States from certain dates. Several of the subsequent amendments specified stricter limits (see Figure 12).

By Council Decision 97/836/EC [9], the European Community acceded to the Agreement of the United Nations Economic Commission for Europe (UNECE) concerning the adoption of uniform technical prescriptions for wheeled vehicles (the 1958 agreement). This ensures that the EU vehicle type approval is harmonised with a broader range of countries outside the EU, such as Russia, Australia, and Japan. A further development in this direction is the "1998 agreement" on world wide harmonization which is also acceded by countries such as USA, China and India. The current set of Global Technical Regulations (GTR's) however does not include any noise items yet. Initial ideas to convert the new vehicle noise test method into a GTR have been abandoned.

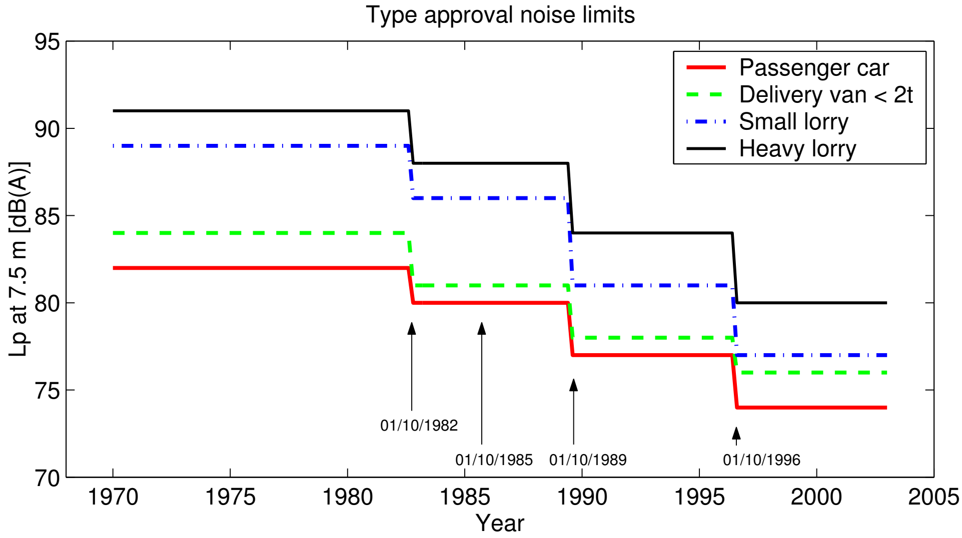


Figure 12 - Historical development of EU road vehicle type approval noise limits: Passenger car, delivery van (2 – 3.5 tonnes max. weight), small truck (> 3.5 tonnes and < 75 kW) and a heavy truck (> 3.5 tonnes and □ 150 kW), including important dates of amendments and adaptations.

Although the 70/157/EC Directive [1] succeeded in harmonising the type testing procedure and noise limits, it failed in reducing real traffic noise levels, as especially for cars, real conditions differ from the test conditions, tyre noise increased relative to powertrain noise and the volume of traffic continuously increased.

For this reason, noise from road traffic was also approached in the more recent Directive 2001/43/EC [10] and Regulation No 661/2009 [7] covering tyre noise, and assessment of environmental noise 2002/49/EC [11]. Directive 2001/43/EC proposed mandatory noise limits for tyres, which are expected to be tightened from 2010 and 2016 onwards. The initial limits were so high that most tyres passed, resulting in no reduction in environmental noise in the short term. An extensive study was performed by FEHRL [12], illustrating that quieter tyres are already on the market, and that stricter limits would not jeopardise safety, such as wet grip or rolling resistance.

Table 16 - List of European Directives and amendments related to noise from road traffic

Motor vehicles exterior noise	**Directive / amendment**
70/157/EC	Directive on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles
73/350/EC	Adapting 70/157/EC to technical progress
77/212/EC	Amendment of 70/157/EC
81/334/EC	Adapting 70/157/EC to technical progress

84/372/EC	Adapting 70/157/EC to technical progress
84/424/EC	Amendment of 70/157/EC
89/491/EC	Adapting 70/157/EC (e.a.) to technical progress
92/97/EC	Amendment of 70/157/EC
96/20/EG	Adapting 70/157/EC to technical progress
1999/101/EC	Adapting 70/157/EC to technical progress
2007/34/EC	Amending 70/157/EEC for the purpose of technical progress; introducing test method B for the purpose of monitoring from 6 July 2008 until 6 July 2010
2007/46/EC	Framework Directive - establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles
Tyres	
92/23/EC	Directive relating to tyres for motor vehicles and their trailers and to their fitting
2001/43/EC	Amendment of 92/23/EC introducing noise limits for tyres
Regulation (EC) No 661/2009	Concerning type approval requirements for the general safety of motor vehicles etc., including stricter limit values for tyre rolling noise, that will become valid from 1 November 2012, 1 November 2013 and 1 November 2016.
Environmental noise	
2002/49/EC	Directive relating to the assessment and management of environmental noise

The Environmental Noise Directive (END) 2002/49/EC [11], requires noise mapping of major agglomerations, roads, railways and airports, and action planning. A first round of noise mapping has been completed in 2008 and the END has recently been evaluated [46]. Numbers of seriously affected inhabitants near roads have been quantified, resulting in a more detailed picture of the distribution of noise impact (see Noise Observation and Information Service for Europe: www.eea.eionet.europa.eu). Earlier figures of seriously annoyed inhabitants are confirmed, but it emerges that by far the highest numbers of highly exposed people are in agglomerations, i.e. urban areas. Given the busy traffic on local roads and junctions, and the frequent stop-and-go driving during peak periods, the contribution from powertrain noise from all types of vehicle may be quite significant.

The general need for tighter vehicle noise limits has been driven by the severity of the road traffic noise issue, which has been emphasised in many publications [13]. Since 2000, a number of studies have investigated in more detail annoyance and health effects from road traffic noise showing the scale and urgency of the problem [14]. Also the associated costs and benefits have been put into perspective [15], generally resulting in the conclusion that the benefits of noise reduction at source far outweigh the costs [16] [17].

Subsidiarity and porportionality principles
The subsidiarity principle requires that objectives of proposed action by the European Community are necessary as they are not achievable by the member states. This is still clearly the case for vehicle noise limits, due to the international nature of road traffic, vehicle exports and the potential for national regulations which would otherwise occur. This is exemplified by ongoing incentives and national regulations for quieter vehicles such as the Dutch MIA/VAMIL and PIEK programmes and the Low noise truck sign which is required on alpine transit routes (Austria; new vehicles generally comply).

The principle of proportionality states that any Community action should not go beyond what is necessary to achieve satisfactorily the objectives which have been set. Given the current levels of environmental noise and affected citizens, and the fact that EU noise limits have not changed in the last decade despite increasing traffic levels, a change in limits to help remedy this situation is considered proportional. Many other local instruments are also applied to reduce traffic noise, but need to be matched by noise reduction at the source, which is far more effective both technically and economically.

7.3 Trends relevant to the Directive

Since the introduction of the Directive, a series of trends have taken effect:
- Continuous growth in traffic volume on all road types, and thereby an increase in numbers of noise exposed citizens.
- Increased awareness of health effects and costs of environmental noise, especially for road traffic noise which is considered one of the main sources.
- Recently, availability of European noise mapping data and exposure statistics of the population (2009).
- Extensive research including EU projects, resulting in detailed knowledge on noise reduction, research roadmapping (CALM), but also environmental impacts and external costs.
- Increasing environmental legislation, both from the EU and at local level, resulting in noise abatement programs such as noise barrier programmes, quieter road surfaces, traffic flow control and rerouting, access limitations and incentives for quieter vehicles and tyres.
- Increasing industry regulation in relation to safety, exhaust emissions, noise and others, resulting in complex and interacting design requirements.
- Reduction of powertrain noise due to improved engine design, including techniques such as electronic engine control, direct fuel injection for diesels, improved balancing, structure optimisation, improved exhaust, intake and shielding design.
- Reduced noise emission from diesel engines, in particular for cars now with comparable noise levels to petrol engines.
- Increased use of diesel engines and in particular an increase in numbers of vans (light commercial vehicles).
- Use of wider tyres, resulting in higher noise emission.
- Increased weight of cars due to high power and additional structural components, resulting in more noise.
- Market shift towards environmentally friendly and alternatively powered vehicles such as hybrid, biofuel, fuelcell, hydrogen and electric vehicles, especially for buses, municipal and municipal vehicles but also for cars.
- Since 2008, a general drop in market demand due to the recession.

Currently, it is estimated that tens of millions of citizens are seriously annoyed by road traffic noise, with exposure levels of L_{DEN} > 55 dB(A). Given the known effects on health, quality of life and consequential costs, real reductions in noise exposure are urgently required.

7.4 Main impacts of reducing vehicle noise levels

The main stakeholders affected by the Directive are

- the public, citizens affected by road traffic noise and their interest groups;
- road authorities, local and national authorities;
- the automotive industry including suppliers and type approval bodies;
- the consumer market for road vehicles: individual car owners;
- the professional market for road vehicles: lease and rental companies, truck, van and taxi fleet owners.

As the Directive is closely linked to UNECE regulations, it also has an international impact worldwide. Countries outside the EU will also benefit from reduced traffic noise levels if the same standards are applied for vehicles imported from the EU.

The various impacts of reducing vehicle noise levels are listed for each stakeholder in Table 17. These impacts are only relevant if the reduced levels actually occur in practice and not only in the type approval test. No distinction is made here yet as to how the reduction is achieved, either by reducing tyre or powertrain noise.

A reduction in vehicle noise emission may affect noise at dwellings differently depending on the immission quantity considered: L_{DEN}, L_{night} or individual events.
- L_{DEN} is the weighted energy average of day-evening-night levels and strongly depends on the road type, the location and traffic variation during a 24 hour period. In many cases, the numbers of cars are so much larger than other vehicle types that they tend to determine the overall L_{DEN} level, often dominated by the evening or night levels as these have stronger weighting. Along some roads heavily used by freight vehicles, lorries and HGVs can sometimes dominate the L_{DEN}.
- The L_{night} is mostly dominated by the higher numbers of cars, as most goods traffic on urban roads runs in the daytime. It contains a mix of powertrain and tyre noise, but more powertrain noise for intermittent traffic flow. On routes with significant nighttime freight traffic such as some motorways, lorries and HGVs can sometimes dominate the L_{night}.
- Single events with high noise levels which do not determine the L_{DEN} or L_{night} may be a significant source of annoyance, for example due to faulty or illegal exhausts or agressive driving. Single events causing annoyance are mainly due to engine noise, often at high and intermittent engine speeds (for example revving engine, fast acceleration, noisy exhaust) and for vehicles with higher than average noise levels such as sports, SUV and off-road vehicles. Another example of single events is the noise experienced near bus stops, construction sites or freight access roads where aceleration and deceleration noise is periodically repeated without necessarily dominating the L_{DEN} or L_{night}.

Table 17 - Stakeholders and general effects of reducing vehicle noise levels. The +/- sign indicates a positive or negative effect.

Stakeholder	+/-	Effect
1. The public affected by road traffic noise	+	a) Improved sleep, reduced stress, improved health and quality of life; indirectly, savings on health and effectiveness at work and school.
	+	b) Increased property value.
	+	c) Improved living, work and recreation environment.
2. Road authorities, national and local authorities	+	a) Reduced need for noise abatement programmes (barriers, road surfaces, sound insulation) and cost saving; easier planning of new or upgraded roads.
	+	b) Less local protest.
	+	c) Less need for regulation and enforcement.
3. Health authorities and government	+	a) Reduced heathcare costs.
4. The automotive industry (OEMs, tyre and supplier industry)	-	a) Increased costs for extra noise control including design, testing and materials; in particular for lorries, buses and trucks.
	-	b) Balancing of noise requirements with other design constraints such as weight, fuel consumption, exhaust emissions, cooling and space.
	+	c) Improved environmental image as a sales point.
	-	d) In some cases, conflict with sound perception of SUVs, sports and luxury cars.
	-	e) Tampering or cycle beating may occur to avoid noise reduction cost/effort.
5. Consumer market	-	a) Cars: small price increase.
6. Professional market	-	a) Price increase, mainly for lorries, trucks and buses.
	+	b) Some market advantage for new fleets, for example rental cars and vans, taxis, buses, delivery or municipal vehicles in urban environment or quiet areas. Benefits from tax incentive programmes or privileged access to sensitive areas.

7.5 Environmental impact

7.5.1 Lowering vehicle noise levels

Lowering vehicle noise limits is intended to reduce the environmental noise impact from traffic noise on the population. In terms of current legislation this is the time averaged equivalent noise level L_{DEN} and the averaged nighttime noise level L_{night} at facades of dwellings, calculated as required by the Environmental Noise Directive 2002/49/EC [11]. Noise levels are presented in noise maps, on the basis of statutory noise prediction models. Data from noise maps of agglomerations and major roads is used to assess numbers of affected people. This data is not yet accurate due to uncertainties in input data and variation in calculation methods used in the member states [46].

Recent noise mapping in the EU [18] has however confirmed the magnitude of the traffic noise issue, showing that in terms of numbers of people affected, the main problem is in urban areas, where both traffic intensity and population density are high, and much of the population lives close to roads.

The main effects of exposure to traffic noise are annoyance, sleep disturbance and health effects, concentration loss, speech intelligibility and general quality of life. A commonly used measure for noise impact is the percentage of seriously annoyed people with $L_{DEN} \geq 55$ dB (at the dwelling facade).

The EEA report 'Transport at a crossroads 2008' [19] gives the following information on exposed people: "Almost 67 million people (i.e. 55 % of the population living in agglomerations with more than 250 000 inhabitants) are exposed to daily road noise levels exceeding 55 dB L_{DEN} (the lower benchmark for the combined noise indicator). With almost 48 million people exposed to levels exceeding 50 dB L_{night}, (the lower benchmark for night-time noise) road noise is also by far the largest source of exposure to night time transport noise. Almost 21 million people (i.e. 17 % of the population living in agglomerations with more than 250 000 inhabitants) live in areas where night-time road noise levels have detrimental effects on health. Road noise again is the main source of transport noise hot spots in these agglomerations."

The vehicle emission data used as input for noise mapping models is a fleet average over all vehicles and is typically updated infrequently (every 5-10 years), if significant changes occur. It generally has only a moderate relation with type testing data as it is obtained from statistical pass-by tests of vehicles of varying condition and age. This means that at any one point in time, as the traffic consists of vehicles of different ages, the average noise level may differ from what might be expected based on the present day type test limits. The vehicle emission level in real life can actually be higher or lower than this average due to loading, driving behaviour or wear. The daily impact can also be significantly different to calculated average levels if the traffic intensity or road surface differs from the assumed inputs.

The effect of limit changes on vehicle noise levels under real conditions depends on whether tyre or powertrain noise is dominant, which in turn depends on road surface, vehicle design, operating condition (see Figure 13), driving style and wear.

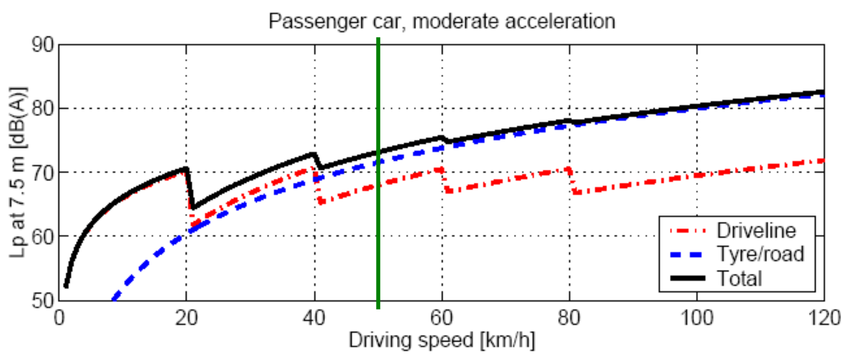


Figure 13 - Illustrative example of the contribution of powertrain and tyre/road noise source of an average, moderately accelerating passenger car with a five speed gearbox, as function of vehicle speed. The green line indicates the approximate speed of the type test.

Over the past decades, noise limits have been reduced, but tyre/powertrain noise ratios and the test method have also changed. This complicates the task of environmental impact assessment. Therefore the analysis is made in terms of most characteristic vehicle categories and most relevant traffic situations with present day data as the starting point.

The importance of intermittent traffic, which includes accelerating traffic, is shown in Figure 14, illustrating the frequency of gear usage as a function of speed in urban traffic, from [20].

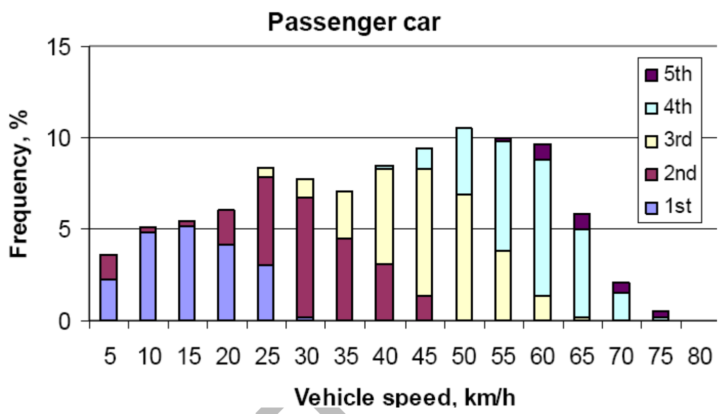


Figure 14 - Frequency of gear usage for different speeds for passenger cars in urban traffic, from [20].

7.5.2 *Analysis*

The environmental impact analysis is mainly intended to compare the effects of changing noise limits and measurement method, therefore a calculation procedure is applied that results in an L_{DEN} level that is approximately representative for key road types in the EU.

Whereas in earlier studies [21], [4], roads were grouped into residential roads, main streets, arterial roads and motorways, all with different speed limits, here a smaller group of average speeds is chosen but also a distinction is made between road sections with free flowing and with intermittent traffic. This is done to be able to estimate the number of people effected by powertrain noise in comparison with situation with combined powertrain and tyre noise or predominantly tyre noise. The road types and their assumed lengths in the EU27 are indicated in Table 18 below. The total road length in the EU27 is 5032125 km, with the deduction discussed in the next paragraph it is reduced to 2882401 km. Road lengths have been derived from several sources including Eurostat and national authorities such as the UK (DfT) and German road authorities and the Dutch statistical office CBS. A distribution between the different road types was based on limited data in different formats. There can be strong variations in relative road type lengths between individual countries, but also the exact definition of national road types is not always clear and can differ between countries.

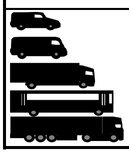
For each road type a correction (deduction) is made for the part without dwellings, for example farmland along rural roads and motorways, commercial or public buildings on urban roads and parks and open areas along residential roads (see also Table 18). Some roads also have traffic restrictions or very low traffic volume. As a consequence an estimated 49 million, about 10% of the population, is hardly exposed to traffic noise. The population for the EU27 is taken at 500 million in 2010; the numbers of inhabitants per dwelling are taken at 2,4, all based on Eurostat data.

In Table 19, road types and lengths are listed together with average numbers of exposed people, typical distance to the dwelling and characteristic noise sources from the different vehicle groups. Numbers of exposed people per road type are based on various estimates from noise mapping and municipal demographic data.

Table 18 - Overview of road types and lengths with corrections for non-residential stretches, roads with restricted access and low traffic volume.

Road type	Assumed % length	Road length kkm	Adjustment	Deduct	Effective length kkm	%intermittent	%freeflow
Residential	33,0%	1661	nonresid., restricted or low intensity	35%	**1079**	**33%**	67%
Main	5,0%	252	nonresid.	20%	**201**	**33%**	67%
Arterial	2,0%	101	nonresid.	10%	**91**	**0%**	100%
Urban Mwy	0,1%	5	nonresid.	20%	**4**	**0%**	100%
Rural Mwy	1,9%	96	nonresid.	50%	**48**	**0%**	100%
Rural road	58,0%	2919	nonresid.	50%	**1459**	**0%**	100%
Total	100,0%	**5032**			**2882**		

Table 19 - Overview of road (sub)types, lengths, exposed inhabitants, exposure distance, noise penalty and typically predominant noise sources

Road type	Residential (urban/ suburban)	Residential (urban/ suburban)	Main roads (urban/ suburban)	Main roads (urban/ suburban)	Arterial roads (urban/ suburban)	Urban motorways (urban/ suburban)	Rural motorways	Rural roads	Total
Traffic type	intermittent	free flow	intermittent	free flow	free flow	free flow	free flow	free flow	
Speed range	V<50	V<50	V<50	V<50	50<V<70	70<V<120	80<V<130	50<V<100	
Full road length(km)	547998	1112603	83030	168576	100643	5032	95610	2918633	5032125
Percentage of total road network	11%	22%	2%	3%	2%	0,1%	2%	58%	100%
Selected road length (km)	356199	723192	66424	134861	90578	4026	47805	1459316	2882401
Percentage of selected road network	12%	25%	2%	5%	3%	0,1%	2%	51%	100%
Estimated avg. exposed inhabitants/km	250	250	500	500	500	1000	50	20	
Typical distance to road (m)	15	15	15	15	15	50	50	50	
Applied penalty, dB	3	0	3	0	0	0	0	0	
Noise sources									
	Powertrain, tyre	Tyre, powertrain	Powertrain, tyre	Tyre, powertrain	Tyre	Tyre	Tyre	Tyre	
	Powertrain	Powertrain, tyre	Powertrain	Powertrain, tyre	Powertrain, tyre	Powertrain, tyre	Powertrain, tyre	Powertrain, tyre	

Urban and suburban residential and main roads also include roads in smaller towns and villages. Main roads can be identified by their transit function, whereas for residential roads most traffic is to or from the dwellings along the road. Arterial roads are characterised by their transit function, but also higher speeds and traffic flow.

Intermittent traffic conditions cause frequent variation in vehicle engine speeds due to gear change and acceleration/deceleration. It occurs at junctions, crossings and traffic lights, but also in residential areas with traffic humps and obstacles, and is known to be more annoying than continuous noise from a free traffic flow of similar noise level [22]. A penalty adjustment of 3 dB for intermittent noise is assumed, based on this finding (an even higher adjustment may be appropriate). A general estimate of the percentage of urban/suburban roads with intermittent traffic made for the purpose of this analysis is one third, 33% of the total urban length of residential and main roads. This assumption can be supported by considering the average distance required for acceleration (from first to third gear) and deceleration (often using the engine) and the average distance between stopping points such as junctions, crossings and traffic lights. The distance affected near any junction is in the order of 100 meters on either side. For an urban road length of 1 km, then at least 200 m has accelerating or decelerating traffic. However, most urban roads have more frequent junctions, crossings or traffic lights, so this length is easily much more than 200 m. Illustrative databased on vehicle test cycles used in emission studies is included in Appendix B.

Arterial roads, motorways and rural roads have a lower percentage of accelerating and intermittent traffic, due to the longer uninterrupted stretches of road and higher speeds. At typical speeds for such roads, tyre noise often exceeds powertrain noise. Exceptions to this are roads with smooth surfaces and a high proportion of lorries and heavy goods vehicles (HGVs), for example transeuropean motorways, and roads with significant gradients. Intermittent traffic typically includes accelerating and decelerating vehicles with a lower average speed and with a significant contribution from powertrain noise, especially for vans, SUVs and sportscars, lorries, buses and HGVs. If roads with gradients are also included, which also increase powertrain noise for uphill traffic, then the percentage of roads with intermittent noise may be even higher than 33%.

The vehicle groups selected for this analysis are cars, vans, buses, lorries and HGVs.

The average L_{DEN} and L_{Night} for typical EU roads is estimated from the following parameters:

- road type;
- vehicle type and speed;
- traffic type: intermittent or free flowing;
- traffic intensity in vehicles/hour for each vehicle type and for day/evening/night periods;
- a representative noise emission level for each vehicle type in each road situation;
- total road length in the EU27;
- average distance of dwelling facades to the road.

Reflections and attenuation effects are not taken into account here, even though in some situations an increase in exposure levels can occur such as in narrow streets or street canyons.

The total road length for each road type in the EU is based on available data from Eurostat and some national authorities. Assumptions have been made on percentages of road not relevant for analysis, such as non-residential roads, restricted access roads and roads in commercial and industrial areas. The traffic type (intermittent or free flowing) only varies for residential and main urban roads. The noise emission levels are based on an existing database of urban traffic measurements [23] which can be related to type test results. The traffic intensity is estimated based on available noise mapping data but also considering the potential variation in European member states. The average distance between the road and the dwelling façade is based on the road type and its typical speeds and traffic flow. For arterial roads and motorways with high speeds and traffic intensity, more dwellings are affected per kilometre than residential and main roads. The calculated L_{DEN} results have been compared with recent urban noise maps and were found to be realistic.

Traffic intensity data and vehicle noise emission levels are given in Appendix C. The equivalent sound pressure level at a characteristic distance from the road is calculated on the following basis.

First, a maximum pass-by level $L_{Amax, rep}$ representative of real operating conditions is derived for each road and vehicle type. This differs for each policy option. The level is based on an UBA database [23] and is adjusted according to the following principles

1. For policy option 1, noise emission values are based on method A current limit values. For the other policy options, noise emission values are based on method B and equivalent limit values according to Option 3.
2. All vehicle categories and subcategories are clustered into 5 groups:
   Group 1 – Passenger cars = Cat M1 + Cat M1G
   Group 2 – Busses = Cat M2 > 3,5 t + Cat M3
   Group 3 – Vans = Cat N1 + Cat N1G + Cat M2 < 3,5 t
   Group 4 – Lorries = Cat N2
   Group 5 – Heavy Trucks = Cat N3 + Cat N3G
3. For each group the weighted average limit values for each policy option are determined with weighting factors based on numbers of vehicles in the Circa database.
4. For all policy options, the shifts in average noise emission per group in normal traffic are assumed to be equal to the shifts in limit values per group.
5. The changes of the average noise emission per group for the various policy options are derived from the test results for test B in the Circa database. For the smaller vehicles, the noise emission is split in accelerating and free flowing traffic conditions. The WOT test result of test method B is attributed to accelerating vehicles (intermittent traffic) and the constant speed test result is attributed to free flowing traffic. For the larger vehicles only the acceleration test results are available, which are used for both intermittent and free flowing traffic.
6. The actual average noise emission values per group in real traffic are extracted from the UBA report [23]. In this report the noise emission per vehicle as a function of driving speed is expressed in regression equations both for accelerating vehicles and for free flow traffic. For the determination of the noise emission, the speed for the small vehicles (Group 1 and 3) is chosen at 50 km/h; for buses 30 km/h and for lorries and trucks 40 km/h. The measurements on which this report is based were done in 2001/2002. In total 29767 vehicles were measured, of which 21729 were passenger cars. The noise emission values from this are considered representative of the current noise emission of European traffic. Therefore these values are used as reference values for the computation of the noise emission effects of the different policy options.
7. The predicted increases and reductions of the acceleration noise and the constant speed noise for the different policy options were added to noise emissions extracted from the UBA report. Options 1 and 3 were both set to be equal to the UBA report

emissions: Option 1 because it represents the current situation and Option 3 because it is tuned to be equivalent to the current situation after introduction of test method B.

8. Option 2 actually implies an increase of the limit values because it employs the current limit values in combination with test method B. As test method B gives lower test results than test method A, keeping the current limit values in fact increases the margin for approval of the noise emission.
9. Options 4 and 5 imply a reduction of limit values which is translated into a reduction of average noise emission values in real traffic. For Option 5, which represents a two step reduction, only the final values have been taken into account. For both options the predicted reduction of the free flowing traffic noise for the smaller vehicles is based on the expected reductions of tyre-road noise due to the adapted rolling noise requirements that will come into force from 2012 according to EC Regulation 661/2009 [7]. For the larger vehicles, the reduction of free flowing traffic noise is assumed to be the same as the reduction of the acceleration noise.

The pass-by level is converted to a sound exposure level L_{Ax} (SEL) at an appropriate distance d from the road, either d=15 m or d=50 m according to

$$L_{Ax,rep} = L_{Amax,rep} - 10\ lg(d/7{,}5) + 5 \quad \text{for d=15m and speeds upto 50 km/h}$$

and

$$L_{Ax,rep} = L_{Amax,rep} - 10\ lg(d/7{,}5) + 7 \quad \text{for d=50m and speeds above 60 km/h}$$

For a series of N pass-bys of the same L_{Ax} level, an equivalent sound pressure L_{eq} level for time period T can be determined from

$$L_{eq} = 10lg\frac{1}{T}\sum_{i=1}^{N}10^{LAx,i/10} = L_{Ax} + 10lg\frac{N}{T}$$

and for K vehicle types and N_k pass-bys of each type during time period T:

$$L_{eq} = 10lg\left(\sum_{k=1}^{K}\ \sum_{i=1}^{N_k}10^{LAx,i/10}\right) - 10lgT$$

This formula can be used to obtain L_{day}, L_{eve} and L_{night}, from which also L_{DEN} can be determined for each road type, vehicle type and traffic intensity and speed.
L_{DEN} is calculated from

$$L_{DEN} = 10\ lg\ [(12/24).10^{Lday/10} + (4/24).10^{(Leve+5)/10)} + (8/24).10^{(Lnight+10)/10}]$$

The overall numbers of seriously annoyed and and sleep disturbed people in the EU for the different road types can be globally estimated from average L_{DEN} and L_{night} levels, average numbers of exposed people along each type of road and known dose-effect relationships (see following section). As intermittent traffic is separately quantified, the part of the population seriously annoyed mainly by powertrain noise can also be assessed.

This procedure can then be repeated for different noise emission data derived for each policy option resulting in the L_{DEN} and L_{night} levels shown below in Table 20.

Table 20 - Calculated average L_{DEN} and L_{night} levels for policy options 1-5.
Coloured fields indicate levels above 55/65/70 for L_{DEN} and 45/55/60 for L_{night}

LDEN	Resid.int.	Resid.free	Main int.	Main free	Arterial	Urban MW	Rural MW	Rural
Option 1	54,4	52,3	67,3	65,3	74,1	71,5	73,6	55,0
Option 2	56,2	54,1	68,9	67,0	75,7	73,1	75,2	56,6
Option 3	54,4	52,3	67,3	65,3	74,1	71,5	73,6	55,0
Option 4	51,6	49,8	64,4	62,9	71,7	69,1	71,1	52,7
Option 5	50,4	49,4	63,2	62,7	71,4	68,9	70,9	52,3
LNIGHT								
Option 1	45,7	43,1	57,0	54,8	65,0	63,4	65,3	46,3
Option 2	47,5	44,9	58,4	56,4	66,7	64,9	66,9	47,8
Option 3	45,7	43,1	57,0	54,8	65,0	63,4	65,3	46,3
Option 4	43,0	40,7	54,2	52,4	62,7	61,0	62,9	43,9
Option 5	41,9	40,1	52,9	52,1	62,4	60,7	62,6	43,5

These predicted levels depend on the traffic intensity by 10 lg (N/T) and therefore increase by 3 dB for a doubling of the intensity.

The differences between the policy options are set out in Table 21, which shows that the effect on L_{DEN} and L_{night} is quite similar, due to the fact that L_{night} in most cases determines the L_{DEN}. Option 2 shows an increase in impact due to the fact that effectively, higher noise levels would be allowed.

Table 21 - Differences in L_{DEN} and Lnight for each policy option.
Zero reductions or increases are coloured red.

dLDEN	Resid.int.	Resid.free	Main int.	Main free	Arterial	Urban MW	Rural MW	Rural
Option 1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Option 2	-1,8	-1,8	-1,5	-1,7	-1,6	-1,6	-1,7	-1,5
Option 3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Option 4	2,8	2,5	2,9	2,4	2,4	2,4	2,4	2,4
Option 5	4,0	2,9	4,2	2,6	2,7	2,7	2,7	2,7
dLNIGHT								
Option 1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Option 2	-1,8	-1,8	-1,4	-1,6	-1,6	-1,5	-1,6	-1,5
Option 3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Option 4	2,7	2,5	2,8	2,4	2,4	2,4	2,4	2,3
Option 5	3,8	3,1	4,0	2,7	2,7	2,7	2,7	2,7

The average reduction in traffic noise levels is taken at 2,5 dB for option 4 and at 3,1 dB for option 5. These reductions are higher in intermittent traffic, 2,8 dB for option 3 and 4,1 dB for option 5. They take effect only gradually, and only are fully in place after all vehicles are replaced, i.e. 13 years after coming into force of the new limits. This is illustrated in figure 11 below. The level of L_{DEN}=72 dB(A) is typical along a busy arterial road. Part of the reduction may occur earlier due to the changes in tyre noise levels, especially for free flowing traffic.

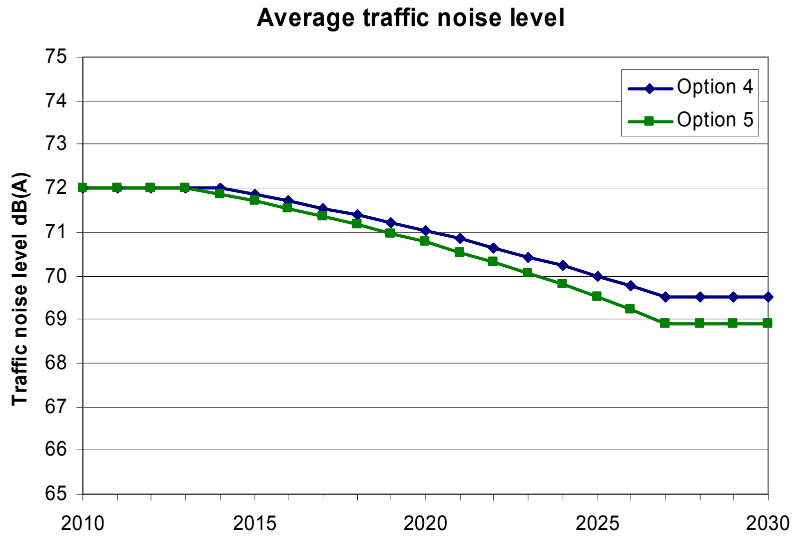


Figure 15: Gradual noise reduction due to vehicle replacement, for policy options 4 and 5.

For single events, the following analysis is made. Single events include occasional vehicle pass-bys with higher than normal noise levels due to

- driving behaviour (excessive acceleration and engine revving);
- modified vehicles (illegal exhausts, modified engines etc.);
- vehicles with defects causing higher noise emission, such as a faulty exhaust, intake, transmission or engine, worn or loose damping and absorption materials;
- vehicles wrongly passed in the type test.

Although relevant for noise impact, vehicles modified without a type test, wrongly passed in the type test and vehicles with defects are not included here.

The main source of single event noise is considered to be powertrain noise at higher engine speeds than for average driving behaviour. A direct relation between WOT type test results and the noise level at the façade is assumed. So the impact of changing noise limits in the 5 policy options is closely related to how well they reflect the WOT test.

The effect on noise levels at the façade is given in Table 22 below for each policy option. There is no straightforward method of assessing the overall impact on the population as single events are somewhat random in time, magnitude and location. The main effect should be an audible reduction in the typical levels of such single events and a slight reduction in incidental severe annoyance and sleep disturbance. Notably, the noise reduction in single event noise levels is larger than the reduction in average L_{DEN} or L_{night} levels.

Table 22 - Effect of each policy option on the reduction of single event powertrain noise. Zero reductions or increases are coloured red.

dLmax	Cars	Vans	Buses	Lorries	HDVs
Option 1	0,0	0,0	0,0	0,0	0,0
Option 2	-2,0	-2,8	-1,4	-2,0	1,0
Option 3	0,0	0,0	0,0	0,0	0,0
Option 4	3,2	3,2	3,0	2,0	2,0
Option 5	4,6	4,4	4,0	3,0	3,0

7.6 Social and health impacts

7.6.1 Main impacts

The social impact of road traffic noise is commonly quantified by the numbers of annoyed people, which is associated with health and quality of life. The annoyance level has been demonstrated to correlate well with L_{DEN} for different types of traffic noise source [24]. In a similar way, sleep disturbance is correlated with L_{night} [25].

For single events such as individual excessively noisy vehicles, less is known about the impact even though such events are well recognized to cause incidental annoyance. If such events are reoccurring, then they can be included in average noise level assessments, otherwise not.

Quality of life covers a range of factors including concentration and speech intelligability at work, home and school, which are difficult to quantify, and quality of residential, recreational and preservation areas, where a quiet environment is valued. Although high noise levels in urban areas affect the most people, increasingly effort is also made to protect some rural areas from traffic noise, which is often present [26]. In terms of health, links have been made to the occurence of myocardial hart disease, hypertension and stress and sleep disturbance [25]. Also estimates have been made of the number of Disability Adjusted Life Years, DALYs, due to environmental factors including noise exposure [14].

The effects of night time noise are discussed in detail in [25]. Some of the effects that can occur at different levels of night time noise exposure are listed in Table 23. The effects of long term night time road traffic noise can be various, as shown in Figure 16 below. The relation is shown between L_{night} levels and numbers of additional awakenings per year, percentage increase in hart attacks, percentage increase in average motility and the percentage of highly sleep disturbed people.

Table 23 - Health effects observed in the population, adapted from [25].

Average night noise level over a year L_{night} (outside)	**Health effects observed in the population**
Upto 30 dB	No observed effects.
30-40 dB	Modest effects including body movements, awakening, arousals, self-reported sleep disturbance. Children, the chronically ill and the elderly are more susceptible.
40-55 dB	Adverse health effects observed among exposed population. Many people have to adapt. Vulnerable groups are more severely affected.
Above 55 dB	Frequent adverse health effects. A high proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

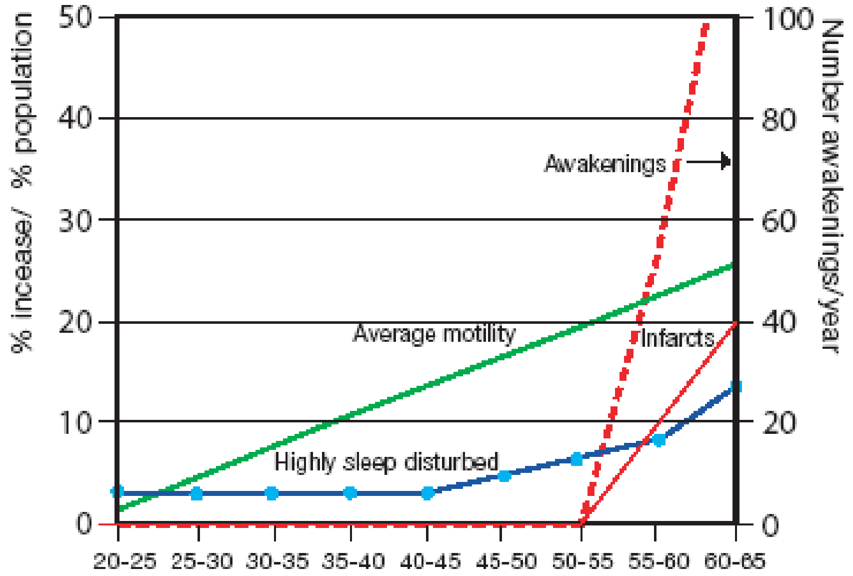


Figure 16 - Effects of road traffic noise at night, from [25]. Average motility and infarcts are expressed in percent increase (compared to baseline number); the number of highly sleep disturbed people is expressed as a percentage of the population; awakenings are expressed in the number of additional awakenings per year.

7.6.2 *Analysis*

Dose-effect curves for annoyance and sleep disturbance developed by Miedema *et al.* and also described in the EU position paper on dose-response relationships [24] , are used here.

Annoyance

The percentage of highly annoyed people %HA is given as a function of L_{DEN} :

$$\%HA = 9{,}868.10^{-4}(L_{DEN} -42)^3 – 1{,}436.10^{-2}(L_{DEN} -42)^2 +0{,}5118.(L_{DEN} -42)$$

The percentage of annoyed people %A is given as a function of L_{DEN} :

$$\%A = 1{,}795.10^{-4}(L_{DEN} -37)^3 + 2{,}110.10^{-2}(L_{DEN} -37)^2 + 0{,}5353(L_{DEN} -37)$$

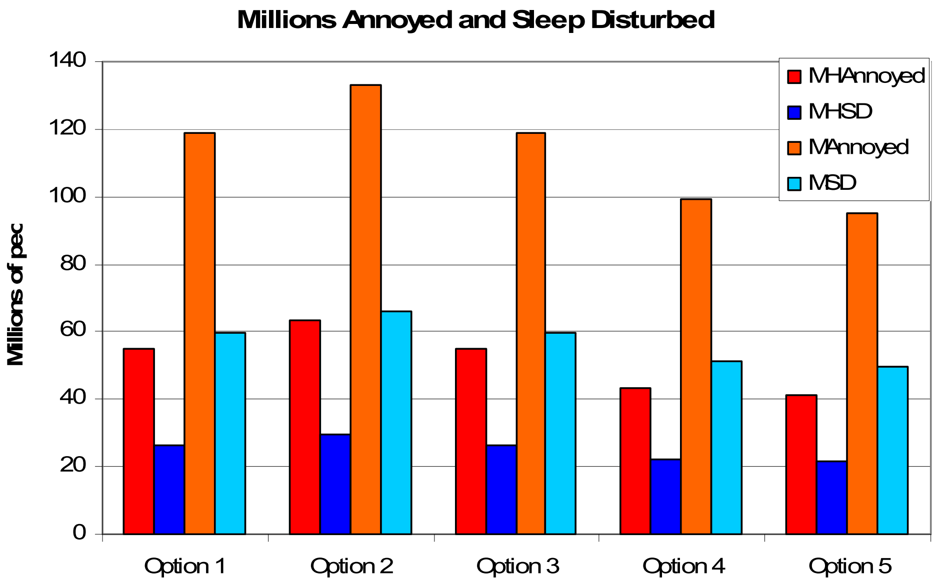
Sleep disturbance
The percentage of highly sleep disturbed people %HSD is given as a function of L_{night} :

$$\%HSD = 20{,}8 – 1{,}05\ L_{night} + 0{,}01486\ (L_{night})^2$$

The percentage of sleep disturbed people %SD is given as a function of L_{night}:

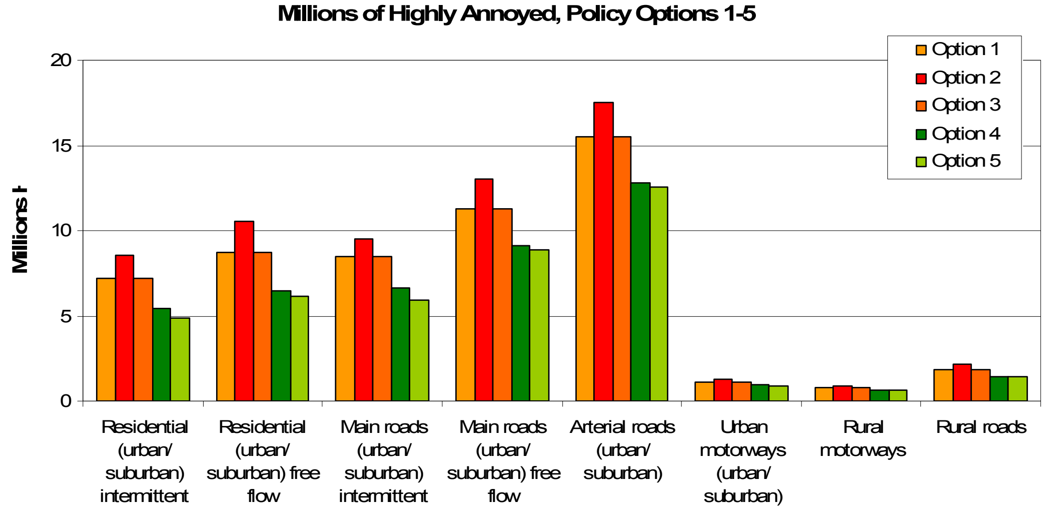
$$\%SD = 13{,}8 – 0{,}85\ L_{night} + 0{,}01670\ (L_{night})^2$$

Estimates for the numbers of highly annoyed and highly sleep disturbed people for each policy option are given in figures 13-15. These estimates are based on the previously calculated LDEN and Lnight levels and exposed numbers of people and the above dose-effect relationships.



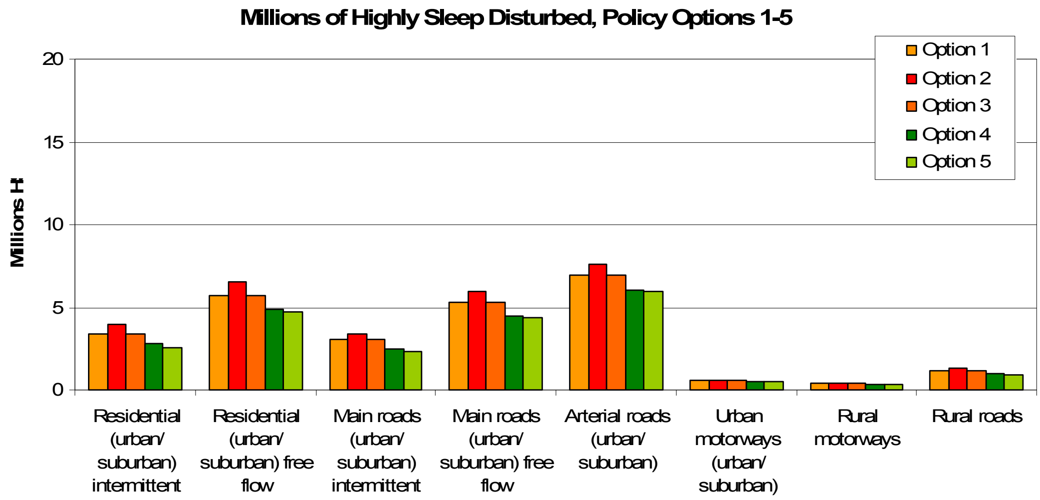
	MHAnnoyed	MHSD	MAnnoyed	MSD
Option 1	55	27	119	60
Option 2	64	30	133	66
Option 3	55	27	119	60
Option 4	44	22	99	51
Option 5	41	22	95	49

Figure 17 - Calculated total millions of highly annoyed/annoyed and highly sleep disturbed/sleep disturbed people for each policy option.



Millions Highly Annoyed	Residential (urban/ suburban) intermittent	Residential (urban/ suburban) free flow	Main roads (urban/ suburban) intermittent	Main roads (urban/ suburban) free flow	Arterial roads (urban/ suburban)	Urban motorways (urban/ suburban)	Rural motorways	Rural roads	Total
Option 1	7,2	8,7	8,4	11,2	15,5	1,1	0,8	1,9	54,9
Option 2	8,6	10,5	9,6	13,0	17,5	1,3	0,9	2,2	63,5
Option 3	7,2	8,7	8,4	11,2	15,5	1,1	0,8	1,9	54,9
Option 4	5,5	6,5	6,6	9,1	12,8	0,9	0,6	1,5	43,5
Option 5	4,8	6,1	6,0	8,9	12,5	0,9	0,6	1,4	41,3

Figure 18 - Millions of highly annoyed people per road type for each policy option



Millions Highly Sleep Disturbed	Residential (urban/ suburban) intermittent	Residential (urban/ suburban) free flow	Main roads (urban/ suburban) intermittent	Main roads (urban/ suburban) free flow	Arterial roads (urban/ suburban)	Urban motorways (urban/ suburban)	Rural motorways	Rural roads	Total
Option 1	3,4	5,7	3,1	5,3	7,0	0,6	0,4	1,2	26,6
Option 2	4,0	6,5	3,4	6,0	7,6	0,6	0,4	1,3	29,8
Option 3	3,4	5,7	3,1	5,3	7,0	0,6	0,4	1,2	26,6
Option 4	2,8	4,8	2,5	4,4	6,0	0,5	0,3	1,0	22,4
Option 5	2,6	4,7	2,3	4,3	5,9	0,5	0,3	0,9	21,6

Figure 19 - Millions of highly sleep disturbed people per road type for each policy option

7.6.2.1 *Disability Adjusted Life Years (DALYs)*

A measure for estimating the effects of disease is the Disability Adjusted Life Years or DALYs, which has been used in [14] to assess the health effects of road traffic noise. The DALY can be related to numbers of highly annoyed people N_{HA} or Highly Sleep Disturbed people N_{HSD} by the following relationships:

$$DALY_{HA} = N_{HA} * N_y * s$$

$$DALY_{HSD} = N_{HSD} * N_y * s$$

Where DALY is the number of DALYs, N_y is the duration of the disease in years set to N_y=1 (in analogy to [14]), and s is the severity, for environmental noise taken at s=0,02 but potentially varying between 0,01 and 0,12.

As there is an overlap in health effects for highly annoyed and highly sleep disturbed people, the number of DALYs is calculated only from the number of highly annoyed. Using the differences in highly annoyed people for each policy option, the resulting annual reductions in $DALY_{HA}$s can be calculated for the above severity range. This is set out in Table 24.

Table 24 - Annual reduction in numbers of DALYs for each policy option, without correction for traffic and exposure growth, based on numbers of highly annoyed people, duration of 1 year and severity s between 0,01 and 0,12.

Reduced DALYs	**Lower estimate**	**Upper estimate**
Option 1	0	0
Option 2	-95.000 (increase)	-1.142.000 (increase)
Option 3	0	0
Option 4	125.000	1.496.000
Option 5	149.000	1.788.000

7.6.3 *Time delays in environmental impact*

If the reduced noise limits actually do affect real vehicle noise levels, they will not fully take effect on the traffic noise until the majority of vehicles have been replaced. This period will typically correspond to the average lifetime of vehicles, about 12 years for cars. In addition, due to the increasing amount of road traffic, the benefits in terms of noise reduction may result in delayed increase in environmental noise instead of a net reduction. Another issue related to the timescale of the environmental impact is the mileage of cars depending on car age. New cars run the highest mileages, especially on motorways, whereas for older cars the mileages reduce by more than half but run more in urban and suburban areas. This effect is illustrated in Figure 20 showing the market penetration of quieter cars over time based on vehicle numbers (fleet size) and on mileage. The annual mileage of quieter vehicles increases more quickly than the percentage of quieter vehicles. The implication is that the impact of reduced noise limits does not benefit urban roads as soon as might be expected.

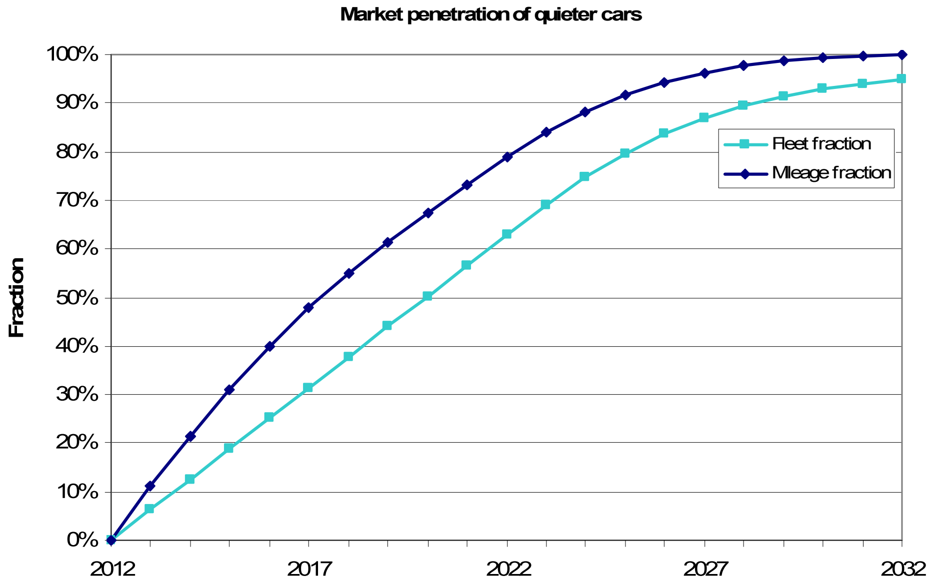


Figure 20 – Market penetration for the percentage of quieter cars in the fleet and the percentage of mileage driven by quieter cars.

7.6.4 *Factors increasing environmental impact*

The environmental impact of road traffic noise has increased fairly continuously over the past 20 years and is, without a change of policy or major technical or economical developments, expected to continue doing so. The main factors for the increase of the number of people that are highly annoyed or highly disturbed in their sleep by traffic noise are the increase of traffic intensities, the construction of new roads, the increase of the total population in general and particularly the relative increase of the urban population.

Over the past two decades, passenger annual car mileage has increased by 1,6 % per year on average. Buses and coaches have an annual mileage increasing by 0,6 % per year and road freight transport mileages have increased by 1,2 %. These growth rates are assumed constant in the calculation of the future impact of road traffic noise.

As the number of highly annoyed and highly sleep disturbed people is related to the total population as a function of the sound exposure, it logically increases with an increasing population. In addition, the already large fraction of the total population living in urban areas (around 50%, and 74% in towns with more than 5000 inhabitants) will increase relatively faster than the population in rural areas. As the population in urban areas is exposed to higher noise levels, the environmental impact is expected to increase slightly faster than for the total population.

The construction of new roads will expose new areas and thereby new people to road traffic noise. The environmental impact of new road construction is however deemed to be small in comparison to the two aforementioned effects.

The total amount of vehicle kilometres is expected to increase a factor 10 faster than the total population in the next 20 years. The analysis of future environmental impact therefore only takes traffic intensity growth into account.

The environmental impact in terms of numbers of highly annoyed and highly sleep disturbed people is obtained by correcting the calculated L_{DEN} and L_{night} levels for the different policy options for the future increase of the traffic volumes. For 1,6% car traffic growth the average increase in L_{DEN} and L_{night} is 0,062 dB per year (0,6 dB over 10 years), for all road types. The average increase in highly annoyed people is approximately 300.000 people/year (0,55%/year) and 100.000 people/year (0,41%/year) for highly sleep disturbed people. The impact of traffic growth over time on numbers of affected people is shown in Table 25. The main implication of continuing traffic growth is that traffic noise reductions and associated benefits will be diminished.

Table 25 - The predicted number of highly annoyed (HA) and highly sleep disturbed (HSD) people in millions for the different policy options until 2030 (Options 4, 5 with immediate effect from 2010).

	2010		**2015**		**2020**		**2025**		**2030**	
	HA	HSD	HA	HSD	HA	HSD	HA	HSD	HA	HSD
option 1	55	27	56	27	58	28	60	28	61	29
option 2	64	30	65	30	67	31	69	32	71	32
option 3	55	27	56	27	58	28	60	28	61	29
option 4	44	22	45	23	46	23	47	24	49	24
option 5	41	22	43	22	44	22	45	23	47	23

The development of the average noise emission level of the whole car fleet taking fleet growth and increased mileage into account is shown in appendix C4 for options 4 and 5.

7.7 Economic impacts

7.7.1 Introduction

The main economic impacts of policy options 1-5 are the technical economic impact which is mainly borne by the automotive industry, and the social-economic impact which is borne by society. In the following subsections, first the annual costs and benefits are calculated for each aspect based on best available input data. This is followed by a comparison of accumulated costs and benefits in terms of net present value in a cost-benefit analysis (CBA).

In the economic analysis the following parameters were chosen:

- Appraisal period – the start year for the CBA is set at 2010 as development of quieter vehicles may already commence then. The end year is set at 2030 (new limits from 2013, average vehicle life of 13 years, this way a complete life cycle of vehicles is covered);
- A discount rate of 3% corresponding to the rate in the Impact Assessment Guidelines of 4%, but reduced with 1% (the 1% reduction is based on the interest rate explained below);
- An interest rate set at 1% (conservative growth rate of the GDP per annum);
- Population growth is estimated to be 1%.

7.7.2 *Technical-economic impact*

The technical-economic impact of changing the directive is mainly for the car industry (manufacturers, suppliers and tyre industry) and consists of changes to the test method and the limits, resulting in costs incurred to achieve noise reductions. The future noise reduction due to quieter tyres is assumed to be ensured by the tyre noise directive, and although some costs may be borne by the tyre industry, quieter tyres are already available on the market for no or little additional price and will be compulsory after 2016.

Additional costs for noise reduction consist of additional production costs per unit, and development, engineering and testing costs, which are relevant for new models or model upgrades.

Additional costs due to administrative burden are not foreseen as the required manpower for testing and administration will not change significantly.

Information sources

The costs for exterior noise reduction borne by industry are estimated here based partly on information from industry, partly on expert estimates by the authors, as very little information on this topic is publicly available. The authors consulted both the automotive industry (ACEA) and independent experts (University of Duisburg-Essen) concerning additional costs in relation to stricter noise limits. The following elements were suggested:

1) Costs can increase exponentially for each dB extra noise reduction.
2) Additional costs will increase significantly if major design changes are necessary, whereas evolutionary changes using existing solutions are less expensive.
3) Additional costs will vary per vehicle type and may increase with shorter development time, but do not depend on the vehicle price.
4) Between 1-2 dB reduction is possible with available technology.
5) The starting point will determine the costs, i.e. if 1-2 dB is already easily achievable for existing vehicles, less extra development effort for these first dBs noise reduction is required.
6) Additional production costs may decrease over time due to increased design integration, efficiency in the production process and lower component and materials costs.
7) Additional production costs are expected to be higher than the additional development costs, in particular for large production series.

ACEA state on their website (see: www.acea.be) and in brochures [37] that around 20 billion Euro is spent annually on R&D, or 4% of total turnover, implying a total annual turnover of around 500 billion Euro. It is not known what part of this R&D funding is dedicated to noise control, but given the unchanged limits over the past decade and the many other design priorities it can be assumed that only a small part is spent on exterior noise reduction.

Scope for reduction, lead time, short and long term solutions

According to the ACEA website, lead times for vehicle development can be upto 5 years, and the product cycle or time they are kept in production is upto 7 years. This implies that fundamental design changes may only come into production after 5 years, and that all existing vehicle models will be fully replaced after 7 years.

Short term solutions for noise reduction for upto 3-5 years ahead may include engine tuning and speed control, engine part damping, shielding and enclosure absorption, quieter engine exhaust and inlet. These solutions are all feasible by modification of existing components and may occur within a normal development process. They may well produce exterior noise reductions of 1-4 dB, although some recent examples are known of larger reductions upto 8 dB, see for example the Dutch PIEK programme (see: www.piek-international.com) which has encouraged some manufacturers to produce special versions of delivery vehicles with very low powertrain noise.

Longer term solutions for further than 5 years ahead may include new engine design or powertrain types, which generally are sought also for improvement of other criteria such as fuel efficiency, exhaust emissions and engine performance. As in the past, the powertrain noise may benefit from engine innovations such as was the case for diesel engines in recent years.

The database analysis showed that for most existing vehicles, there is 1-2 dB scope for noise reduction, based on the compliance rates. This means that for new vehicle models for which the new directive would be applicable, larger reductions should be feasible, as in practice no more noise reduction is applied than strictly required by the limits (see distribution in heavy goods vehicles test results for example, which are all close to the limit).

Analysis
For the purpose of this analysis it is assumed that for all manufacturers all the development costs for exterior noise reduction occur in the 3 years before production of a new model that must comply with new limits. The additional production costs occur during the production cycle of 7 years. As all the current models on the market will gradually be replaced over a period of 7 years, both the development costs and production costs of all models will be distributed over this 7 year period, with the development costs starting before the introduction of each new model, and the additional production costs commencing at market introduction and gradually diminishing over the 7 year period.

The noise reductions are assumed to be achievable by the previously described short term solutions. The additional costs for development and production are estimated on the following basis.

Development costs
Additional development costs are expected over a 7 year period during which new models are developed that must comply with the new limits. The noise reduction must be achieved on powertrains, as tyre noise automatically will be reduced due to the tyre directive. Estimation formulas for both costs are given here, deemed to be consistent with the available information from consulation.

For a noise reduction NR_j for vehicle type j, the total estimated additional development costs for exterior noise reduction $C_{dev,j}$ can be expressed in the following formula, which includes an exponential cost increase:

$$C_{dev,j} = n_j \, . \, C_{dj} \, . \, 2^{(NRj-1)}$$

and

$NRj = NR_j - NR_{0,j}$

where
n_j= number of new vehicle models of group j produced in the EU27
C_{dj} = development cost for 1 vehicle model of group j for first dB reduction
NR = total required exterior noise reduction in dB
NR_0 = margin of noise reduction achievable with available technology, dB

The annual number of new models for each vehicle type is estimated from the EU database, taking into account that many vehicles have similar subtypes. The figures are listed in Table 26.

The average additional development cost C_{dj} for 1 dB noise reduction is estimated at 1 manyear + facility costs, approximately €150.000,-. Such costs are considered to be comparable independent of vehicle group (cars, vans, buses, lorries, HGVs).

Table 26 - Estimated annual additional development costs as function of number of new models nj per vehicle group j per annum, base annual development cost Cdj per dB reduction, reduction margin NR0 and required reductions NR for policy options 4 and 5.

Vehicle group j	n_j	C_{dj} (€)	NR_0 dB	NR option 4, dB	Additional devt. Cost (M€)	NR option 5, dB	Additional devt. Cost (M€)
Cars	225	150.000	2	3,2	37,6	4,6	101,3
Vans	8	150.000	2	3,2	1,3	4,4	3,1
Buses	10	150.000	2	3,0	1,5	4,0	3,0
Lorries	10	150.000	2	2,0	0,8	3,0	1,5
HGVs	15	150.000	2	2,0	1,1	3,0	2,3
Total/year (M€)					42,3		111,1
Over 7 years (M€)					296,4		777,9

An upper limit can be assessed for these costs by estimating a percentage of the total R&D funding for the whole EU vehicle industry, taken here at 1% over 7 years. With an annual R&D budget of 20 billion Euros x 1% = 200 million Euros annually, this would amount to a total of 1,4 billion Euros over 7 years. For option 5, the above formula resulted in around half this amount, 0,78 billion Euros and for option 4, 0,3 billion Euros. These amounts are used here as the upper limit is considered an overestimate. Even the above figures may be an significant overestimate, as many vehicle models show similarities and the solutions used may therefore also be comparable and based on design rules.

Production costs
The additional production costs C_{prod} can be calculated from an estimate for additional materials and manufacturing, assumed proportional to the noise reduction, and slowly decreasing over the lifetime of the production cycle to take into account gradual efficiency improvements in production. The additional production costs are assumed for short term noise reduction solutions, but reducing to zero after 7 years due to gradual

integration and introduction of longer term and more effective design solutions. The following linear relation is assumed between de additional production costs $C_{prod,j}$ for vehicle group j and the noise reduction NR:

$$C_{prod,j} = m_j \cdot C_{pj} \cdot NR$$

where
m_j = number of vehicles of group j produced per annum
C_{pj} = average additional production cost per dB of noise reduction
NR = exterior noise reduction on the vehicle

The value of additional production costs per dB, C_{pj} is estimated at 20 Euro per unit/dB for cars and vans and 120 Euro per unit/dB for other vehicles. The differences between light and heavy vehicles can be approximately related to vehicle mass. These figures are assumed to rise linearly with increasing noise reduction according to the above formula but reduce to zero over the production cycle of the vehicle (7 years). So all additional costs are deemed negligible after 2020.

Table 27 - Annual additional production costs as a function of required noise reduction for options 4 and 5, number of vehicles produced per annum m_j and average additional production cost for the first dB of noise reduction C_{pj}.

Vehicle group j	Number produced m_j	Additional Cost C_{pj} (€)	NR option 4 dB	Additional production cost (M€)	NR option 5 dB	Additional production cost (M€)
Cars	14500000	20	3,2	916	4,6	1330
Vans	2200000	20	3,2	139	4,4	192
Buses	30000	120	2,4	11	3,4	14
Lorries	100000	120	2,0	24	3,0	36
HGVs	100000	120	2,0	24	3,0	36
Total(M€)				1113		1608

Combined development and production costs
The combined costs due to development and production are set out in Table 28 below, showing that the production costs are generally much higher than the development costs, when taken over a 7 year period.

Table 28 - Additional development and production costs in M€ due to options 4 and 5 including a 1% interest rate.

M€	Option 4				Option 5			
Year	Development	Production	Total	+interest 1%	Development	Production	Total	+interest 1%
2010	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2011	42,3	0,0	42,3	42,8	111,1	0,0	111,1	112,2
2012	42,3	0,0	42,3	43,2	111,1	0,0	111,1	113,4
2013	42,3	1113,2	1155,5	1190,5	111,1	1608,3	1719,4	1771,5
2014	42,3	954,2	996,5	1037,0	111,1	1378,5	1489,6	1550,1
2015	42,3	795,1	837,5	880,2	111,1	1148,8	1259,9	1324,2
2016	42,3	636,1	678,4	720,2	111,1	919,0	1030,1	1093,5
2017	42,3	477,1	519,4	556,9	111,1	689,3	800,4	858,1
2018	42,3	318,1	360,4	390,3	111,1	459,5	570,6	617,9
2019	0,0	159,0	159,0	173,9	0,0	229,8	229,8	251,3
2020	0	0	0	0	0	0	0	0,0
2021	0	0	0	0	0	0	0	0,0
2022	0	0	0	0	0	0	0	0,0
2023	0	0	0	0	0	0	0	0,0
2024	0	0	0	0	0	0	0	0,0
2025	0	0	0	0	0	0	0	0,0
2026	0	0	0	0	0	0	0	0,0
2027	0	0	0	0	0	0	0	0,0
2028	0	0	0	0	0	0	0	0,0
2029	0	0	0	0	0	0	0	0,0
2030	0	0	0	0	0	0	0	0,0
Total M€	339	4453	4791	5035	889	6433	7322	7692

The impact on the vehicle industry consists primarily of additional development and production costs due to extra noise reduction on vehicles. The accumulated costs amount to 5 billion Euros for option 4 and 7,7 billion Euros for option 5. These costs are incurred over a development and production cycle of 3+7 years and consist mainly of additional production costs which are no longer incurred after 10 years.

7.7.3 *Social-economic impact*

Following the WHO-report ‘Economic valuation of transport-related health effects, with a special focus on children’ (2008) [34], societal benefits for noise exposure can be identified for various health endpoints. These health endpoints are:

- Severe annoyance
- Sleep quality
- Severe sleep disturbance
- Insomnia
- Ischemic heart disease, with limited strength of evidence in relation to noise exposure.

The included literature study shows that for the typical type of costs which are taken into account in noise exposure studies are the following:

- Costs of medical care (direct costs)
- Economic production losses (direct costs)
- Suffering and grief (intangible costs)

According to the study (p. 77) the costs are mostly measured by means of costs of illness and willingness to pay. Furthermore the studies used the net economic production losses, in other words the loss of consumption due to life lost is not taken into account. To calculate the effects of noise exposure for the costs of illness the value of life years lost is used, instead of the statistical life expectancy. The table on page 81 of the study shows that the total health costs of Switzerland in a specific study [47] are calculated to be 521 million Euro. This gives a first hint of the potential benefits that could be derived if road transport noise is reduced.

According to the WHO-report [34], the health effects should be determined by applying the steps shown below.

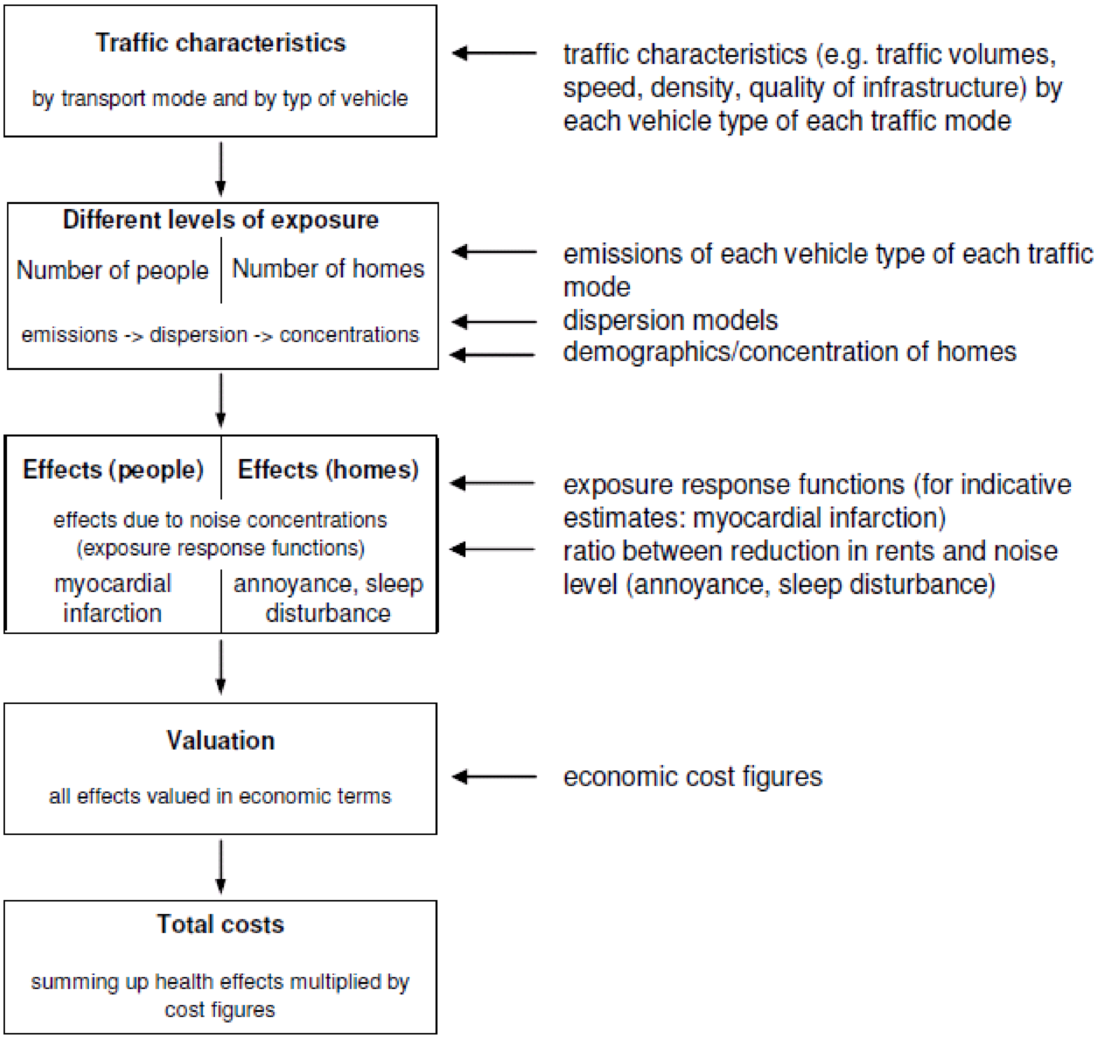


Figure 21 - Steps to determine valuation of health effects, taken from [34].

The first three steps are already made in the environmental impact assessment of this study. Step 4, the valuation, and step 5, stating cost figures, are discussed below.

As seen in Figure 21 two types of effect are distinguished, one for people and one for homes. These two effects are valuated in the following sections together with a third type of benefit that needs to be taken into account. Due to reduction in noise exposure of road traffic, road operators and local authorities save on abatement measures such as noise barriers, quiet road surfaces and dwelling insulation. These benefits also need to be taken into account in the social benefits, since these resources can be spent on other public needs.

The main elements of the social-economic impact are perceived monetised benefits of noise reduction, benefits from savings on health costs and benefits from savings on noise abatement.

Taking the above considerations into account, the overall annual benefits are the sum of each of the hedonic pricing benefits, health savings benefits and noise abatement savings benefits:

$B_{tot} = B_{HP} + B_{health} + B_{ab}$

where
B_{HP} = annual benefit based on hedonic pricing
B_{health} = annual benefit due to health savings
B_{ab} = annual benefit due to savings on noise abatement measures on infrastructure such as barriers, quieter road surfaces and dwelling insulation.

All of these benefits occur annually as a function of the noise reduction, which takes effect gradually over a 20 year period, with a discount rate of 3%.

7.7.3.1 Valuation of noise reduction by hedonic pricing

A recommended method to value the benefits of traffic noise reduction is given in the EU position paper on valuation of noise (2003) [15]. It reflects how much citizens are prepared to pay for noise reduction around their homes, and variation in house prices depending on outdoor traffic noise levels.

The perceived benefit of noise reduction per household per year, based on willingness-to-pay and hedonic pricing calculation methods is a figure of € 25/dB/household/year from 2002. This is an average based on various European studies and is stated to be a low estimate. The valuation of noise reduction found in the literature varies significantly between 2 and 200 Euros, whereas in the Netherlands the variation is between 39 and 200 Euros.

The recommended value of € 25 from around 2002 is used here, and has to be adjusted by an increase due to GDP per capita growth at 1%. In 2010 the value is € 27,- and in 2020 it is €29,80.

The annual hedonic pricing benefit B_{HP} can be derived according to

$B_{HP} = V_{HP} * N_h * NR$

where
V_{HP} = value of hedonic pricing in Euros per household per dB per annum
N_h= number of households (calculated per road type and length)
NR= noise reduction in dB (L_{DEN}).

The benefits are calculated for the number of exposed persons in the L_{DEN} calculation, which is 451 million. Assuming 2,4 persons per household (from Eurostat 2008) the number of households affected N_h is 188 million. Around 10% are assumed not to be significantly exposed due to a housing location free of traffic.

For a noise reduction of 1 dB in 2010, when the valuation V_{HP} is € 27 per dB per household per annum, for the exposed EU27 population of 451 million and an average household occupancy of 2,4 persons, the benefits would amount to 27*451/2,4 = 5074 million Euros/dB. In 2020 for an exposed population of 498,2 million and valuation of € 29,80 the benefits amount to 6186 million Euros/ dB. These figures only differ slightly from the 2006 FEHRL report [12], due to differences in exposed population (10% less), population growth (1% instead of 1,7%), and household size (2,4 person/household instead of 2,45).

The calculation is made for a final average noise reduction of 2,5 dB for option 4 and for 3,1 dB for option 5. The benefits during the appraisal period are listed in tables 24-25.

7.7.3.2 Valuation of health effects

The WHO report on valuation of transport related health effects [34] advises to separate the valuation of annoyance and morbidity (illness) effects. Annoyance and sleep disturbance are valued according to a hedonic pricing principle based on the revealed preference method as discussed above. These do not include health costs. The health benefits are defined in terms of savings on costs due to illness and life years lost. These are valued on the basis of the Value of Life Years Lost (VLYL) and the Cost of Illness (COI):

$$B_{health} = (NR * PR)\sum_i VLYL_i + COI_i$$

NR = noise reduction in dB
PR = per dB prevalence (occurrence) reduction factor = 0.02, see Figure 16
$VLYL_i$ = Value of Life Years Lost for illness i, ischemic heart disease (IHD) or high blood pressure related disease (HBP).
COI_i = Cost Of Illness i for IHD or HBP.

The Value of Life Years Lost is calculated by $VLYL_i = V_i*LYL_i$
V_i = the value of 1 life year lost at € 63.250 and LYL_i the number of life years lost:

The Cost of Illness i is calculated according to $COI_i = CH_i*HD_i$, where
HD_i = the number of hospital days / disease / year and
CH_i = the cost of one day of hospital treatment

Table xx: Number of life years lost (LYL), number of hospital days (HD) and hospital costs (CH) for ischemic heart disease (IHD) and for high blood pressure (HBP)

	IHD	HBP
LYL_i	17.900	46.300
HD_i	50.000	240.000
CH_i	€ 670	€ 540

The estimates LYL_i, V_i, HD_i, CH_i are derived from a Swiss study [47]. LYL_i and HD_i are scaled up in proportion to the ratio of Swiss population (7.6 Million) and that of the EU27 (500 Million). V_i and CH_i are converted from Swiss Francs to Euros at a rate of 1:0,74. For the above formula, the annual health benefits for the EU27 then amount to

84,5 million Euros per dB noise reduction, which is equivalent to € 5,92 per person per dB per year. The benefits during the appraisal period are listed in tables 24-25.

7.7.3.3 Benefits from abatement savings

Benefits from savings on noise abatement due to quieter traffic are assessed by estimating the reduced effective noise levels along roads where normally noise barriers, quiet road surfaces or façade insulation would be required. Noise barriers are typically only applicable for motorways and arterial roads where large noise reductions of 10-15 dB are necessary. Quiet road surfaces are a solution for all road types where tyre noise is predominant, although the reduction potential is limited to around 5 dB for motorways and 2,3 dB for urban situations. Façade insulation, with potentially large reduction potential upto around 30 dB is applicable in all situations but is considered here as one of the few available solutions for main and arterial roads in urban areas.

Other solutions such as traffic restrictions, rerouting and speed restrictions are also possible, but tend to have relatively low costs and are not always applicable. These options are therefore not included in the analysis.

The savings are calculated here assuming a critical noise level that requires action to be taken to reduce noise levels. Figures on overall noise abatement spending are difficult to obtain for the whole EU as investment levels differ strongly between countries and even within countries there can be large differences between national and local authority abatement programmes and available funding. There is also a difference in investment levels for new roads and existing ones, as it is easier to factor in costs for noise barriers on new roads.

In situations where the traffic noise is a upto 3 dB above the threshold for noise abatement, a reduction in traffic noise due to policy options 4 and 5 can enable the road authority to avoid some investments. In other situations it may be possible, due to reduced traffic noise levels, to apply quiet road surfaces instead of more expensive noise barriers or façade insulation.

The benefits of savings are therefore calculated for avoided noise abatement and for reduced noise abatement. This is done separately for situations where barriers may be applied and in the urban situation where noise insulation is used.

Noise barriers are the conventional means of abatement along urban and rural motorways and arterial roads. The current weighted average L_{DEN} at these roads is given for the current situation and policy options 4 and 5 in Table 29 below. See for typical L_{DEN} levels for these road types Table 20 in the environmental impact analysis.

Table 29 - Differences in LDEN for arterial roads, urban and rural motorways and average for these road types weighted by number of exposed inhabitants.

	L_{DEN} Current	L_{DEN} Option 4	L_{DEN} Option 5	Millions of exposed people
Arterial roads	74,1	71,7	71,4	45
Urban motorway	71,5	69,1	68,9	4
Rural motorway	73,6	71,1	70,9	2
Weighted average	73,9	71,5	71,2	51

The weighted average L_{DEN} in the current situation is used as the mean of a normal distribution of sound levels in abatement situations where noise barriers are required. The standard deviation is assumed to be 3,75 dB, thus placing more than 95% of the abatement situations within a +/- 7.5 dB range, i.e. between 66 and 81 dB. The L_{DEN} for policy options 4 and 5 is also assumed to be normally distributed with the weighted average as mean and a standard deviation of 3,75 dB.

The abatement threshold level is set at 65 dB, which is representative for most European countries and the road situation. The noise abatement to be expected from quiet road surfaces in these situations is 4,5 dB. Figure 22 shows the current L_{DEN} distribution for barrier abatement situations and the distribution after the policy change. The fraction of situations where no abatement is necessary and situations where less expensive abatement can be achieved increases after the policy change. The benefit is calculated by subtracting the fractions before the policy change from the fractions after.

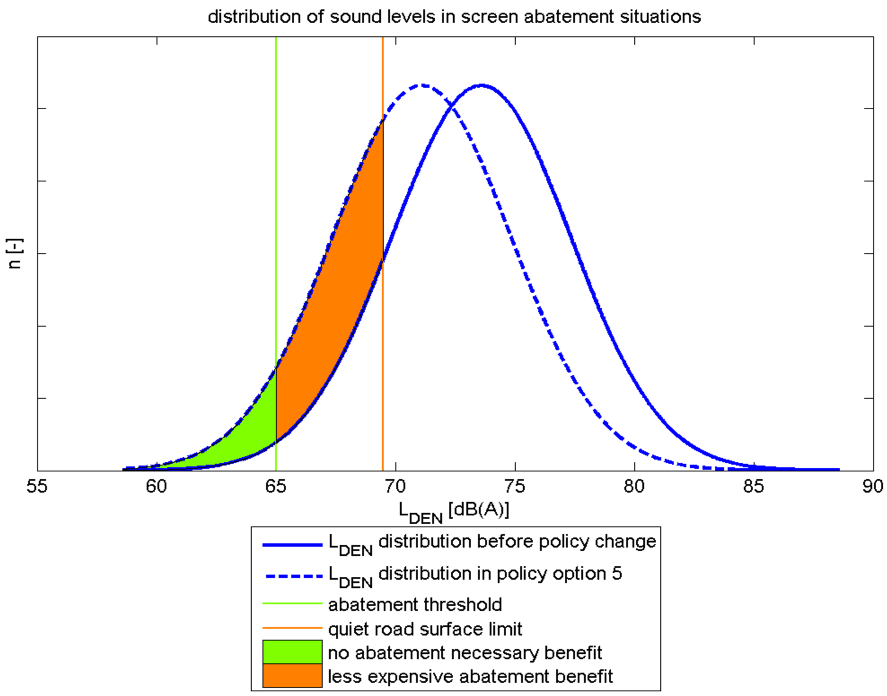


Figure 22 - Noise level distribution in situations where typically noise barriers would be required, and shift due to policy option 5 including benefits due to avoided costs and due to less expensive abatement.

Therefore the portion of situations where no abatement is needed (green area) can be written as

$$B_u = P_f(x \le T_a) - P_c(x \le T_a)$$

where P_f is the future total fraction of unnecessary abatement situations
P_c is the current total fraction of unnecessary abatement situations
T_a is the threshold level for abatement (dB)

The fraction of abatement situations where a less expensive substitute suffices (orange area) is written as

$$B_s = P_f(T_a > x \le T_a + L_s) - P_c\left(T_a > x \le T_a + L_s\right)$$

where L_s is the threshold below which alternative abatement measures can be taken such as quiet road surfaces.

It is estimated that in the EU27 in 2010, 500 million Euros are spent on 290 km of traffic noise barriers. This is considered a conservative estimate and is based on data from Germany [41], also taking into account lower expenditure levels in other member states. The annual benefits in terms of savings in situations where spendings on noise barriers are unnecessary or less expensive are shown for policy options 4 and 5 in Table 30.

Table 30 - Percentage of savings on noise barriers due to options 4 and 5. B_u = benefits from unnecessary/avoided abatement measures, Bs= benefits from reduced or substitute measures.

	B_u (%)	B_u (M€)	B_s (%)	B_s (M€)	B_u+B_s (M€)
Option 4	3,3%	16,5	10,7%	22,5	39,0
Option 5	4,1%	20,3	16,5%	34,6	54,9

In urban situations, abatement of traffic noise on main roads is achieved with the application of quiet road surfaces or façade insulation. The analysis is performed using the same approach as above, with the abatement threshold T_a=60 dB, the quiet road surface limit L_s = 2,3 dB and the L_{DEN} for the current situation and policy options shown in the Table 31 below.

Table 31 - Differences in LDEN for main roads with intermittent and free flowing traffic and average for these road types weighted by the number of exposed inhabitants.

	L_{DEN} Current	L_{DEN} Option 4	L_{DEN} Option 5	Millions of exposed people
Main intermittent	67,3	64,4	63,2	60
Main free flowing	65,3	62,9	62,7	121
Weighted average	66,0	63,4	62,9	181

The weighted averaged L_{DEN} values are again taken to be the mean of normal distributions with a standard deviation of 3,75 dB.

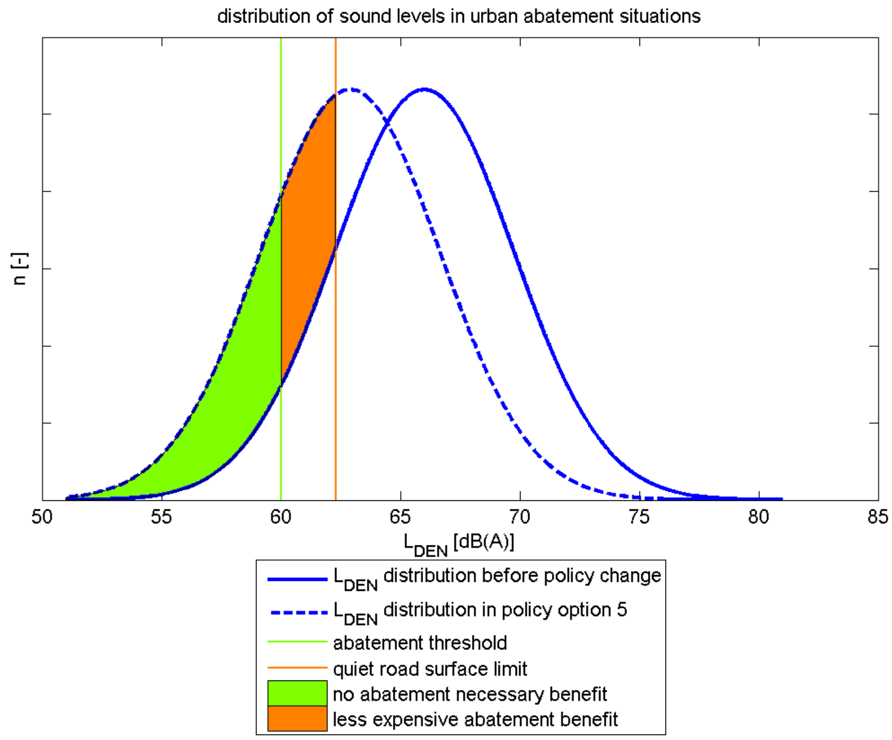


Figure 23 - Noise level distribution in situations where typically façade insulation or quiet road surafes would be required, and shift due to policy option 5 including benefits due to avoided costs and due to less expensive abatement measures.

The fractions of situations where no or less expensive abatement measures can be taken and the corresponding savings are set out in Table 32 below.

Table 32 - Annual savings on façade insulation due to options 4 and 5.

	B_u (%)	B_u (M€)	B_s (%)	B_s (M€)	B_u+B_s (Meuro)
Option 4	12,7%	16	9,8%	3	19
Option 5	16,6%	21	10,2%	3	24

The total annual savings on all abatement measures B_{ab} are estimated for the EU27 in 2010 at 58 M€ for policy option 4 and 79 M€ for policy option 5.
These are comparatively modest benefits compared with HP and health benefits.
The benefits during the appraisal period are listed in tables 24-25.

7.7.4 Comparison of costs and benefits for each policy option

The social, health and abatement benefits are now compared to the industry costs based on the annual rates determined in the previous sections and taking into account growth effects and discounting.

Annual costs and benefits for options 4 and 5 are set out in Table 32, Table 33, Figure 24 and Figure 25. The accumulated costs and benefits over the appraisal period 2010-2030 are set out in Figure 26 and the net present values for 2030 are listed in Table 35. All figures are in millions of Euros.

Table 33 - Societal benefits and industry costs of policy option 4.

Option 4								
Year	Acc. noise reduction dB	Social benefits M€	Health benefits M€	Abatmt. savings M€	Total benefits M€	Acc.total ben. M€	Industry costs M€	Acc.total costs M€
2010	0,0	0	0	0	0	0	0	0
2011	0,0	0	0	0	0	0	43	43
2012	0,0	0	0	0	0	0	43	86
2013	0,0	0	0	0	0	0	1191	1276
2014	0,0	0	0	0	0	0	1037	2313
2015	0,2	769	12	4	785	785	880	3194
2016	0,3	1543	34	8	1586	2370	720	3914
2017	0,5	2320	68	13	2401	4771	557	4471
2018	0,7	3099	112	17	3228	7999	390	4861
2019	0,9	3876	166	22	4064	12063	174	5035
2020	1,1	4651	229	27	4908	16971	0	5035
2021	1,3	5420	302	33	5755	22726	0	5035
2022	1,5	6182	383	39	6604	29330	0	5035
2023	1,7	6931	472	46	7449	36779	0	5035
2024	2,0	7666	568	53	8287	45066	0	5035
2025	2,2	8382	672	60	9114	54180	0	5035
2026	2,5	9075	782	68	9925	64104	0	5035
2027	2,5	8723	885	69	9677	73782	0	5035
2028	2,5	8354	983	69	9406	83187	0	5035
2029	2,5	7966	1073	70	9109	92296	0	5035
2030	2,5	7559	1158	71	8788	101084	0	5035

Table 34 - Societal benefits and industry costs of policy option 5.

Option 5								
Year	Acc. noise reduction dB	Social benefits M€	Health benefits M€	Abatmt. savings M€	Total benefits M€	Acc.total ben. M€	Industry costs M€	Acc.total costs M€
2010	0,0	0,0	0	0	0	0	0	0
2011	0,0	0,0	0	0	0	0	112	112
2012	0,0	0,0	0	0	0	0	113	226
2013	0,0	0,0	0	0	0	0	1771	1997
2014	0,1	656,3	10	4	670	670	1550	3547
2015	0,3	1314,2	30	7	1351	2021	1324	4871
2016	0,5	2121,7	61	12	2195	4217	1094	5965
2017	0,6	2933,8	104	17	3055	7271	858	6823
2018	0,8	3748,7	157	23	3929	11200	618	7441
2019	1,0	4564,7	220	29	4814	16014	251	7692
2020	1,2	5379,6	294	35	5708	21722	0	7692
2021	1,5	6191,0	377	42	6609	28331	0	7692
2022	1,7	6996,3	468	49	7513	35845	0	7692
2023	1,9	7792,6	568	56	8417	44262	0	7692
2024	2,2	8576,6	676	65	9318	53580	0	7692
2025	2,5	9344,8	792	73	10210	63790	0	7692
2026	2,8	10093,0	914	83	11090	74880	0	7692
2027	3,1	10816,7	1042	94	11953	86833	0	7692
2028	3,1	10358,6	1163	94	11616	98449	0	7692
2029	3,1	9877,7	1276	95	11249	109697	0	7692
2030	3,1	9373,2	1380	96	10850	120547	0	7692

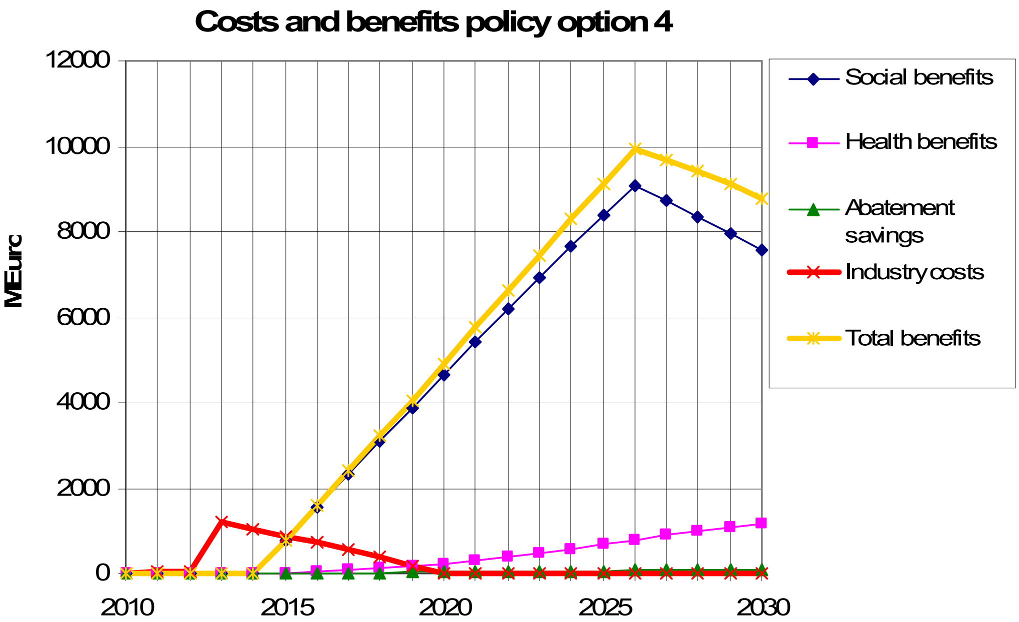


Figure 24 - Societal benefits and industry costs of policy option 4, over 2010-2030

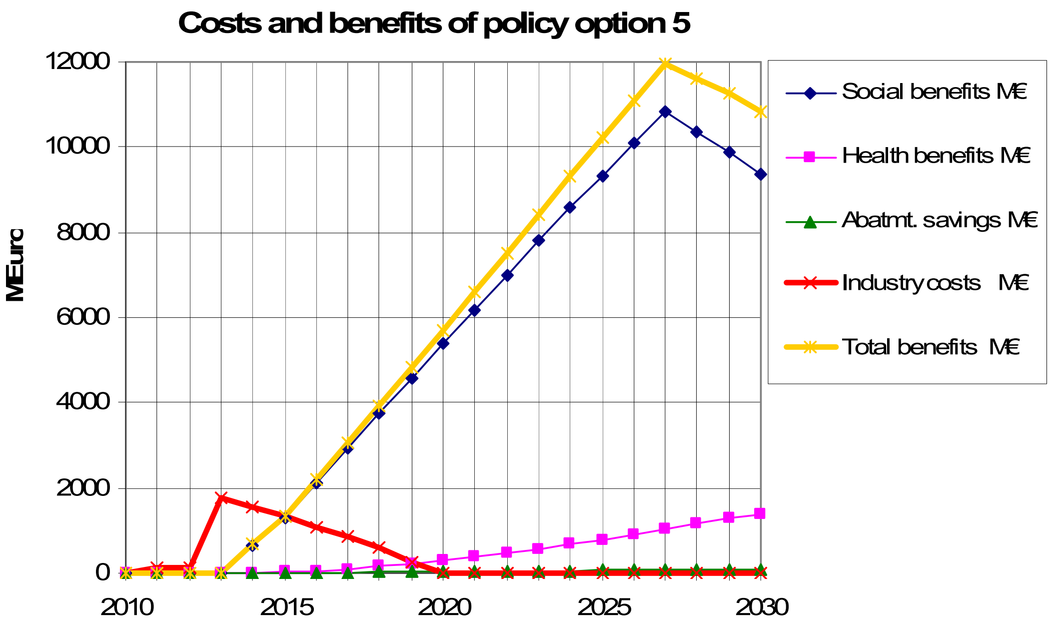


Figure 25 - Societal benefits and industry costs of policy option 5, over 2010-2030

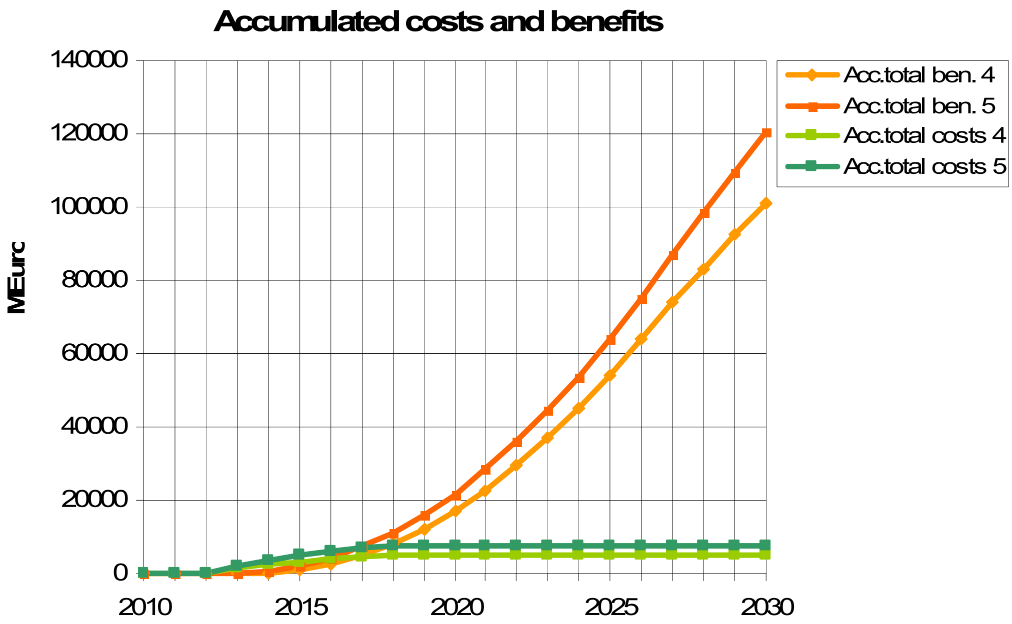


Figure 26 – Accumulated societal benefits and industry costs of policy options 4 and 5, over 2010-2030 (Net present value).

Table 35 - Accumulated societal benefits and industry costs of policy options 4 and 5, Net present value in 2030 (BCR = Benefit - Cost Ratio)

	Benefits M€	Cost Industry M€	BCR
Option 1	0	0	-
Option 2	0	0	-
Option 3	0	0	-
Option 4	101084	5035	20,1
Option 5	120547	7692	15,7

The comparison between overall costs and benefits clearly shows that the societal benefits far outweigh the costs to industry, which are passed on to the customer.
The benefits outweigh the costs by a factor 20,1 for option 4 and a factor 15,7 for option 5.

7.8 Summary of impacts

The environmental impact was determined in terms of effect of the policy options on L_{DEN}, L_{night} and single event levels taking different road types, traffic types and population exposure for each road type into account. Due to high numbers of cars compared to other vehicles on most roads they generally tend be the dominant factor for L_{DEN} and L_{night} levels.

Current levels of L_{DEN} for exposed people along different average road types included in the analysis vary between 52-74 dB and for L_{night} between 43 and 65 dB. Although lower levels occur along residential and main roads than arterial roads and motorways, they are quite significant in terms of impact due to the number of exposed people and the great length of such roads in the EU.

The environmental benefit in terms of noise levels is clearly greatest for options 4 and 5, with reductions in L_{DEN} and L_{night} on average 2,5 dB for option 4 and 3,1 dB for option 5. Higher reductions are reached for roads with intermittent traffic where powertrain noise is dominant, 2,8 dB for option 4 and 4 dB for option 5.
Option 2 results in a net increase in L_{DEN} and L_{night} levels of around 1,7 dB, whilst options 1 and 3 have no effect, reflecting the baseline situation.

Part of the expected traffic noise reduction will be from reduction of tyre noise due to the tyre directive, especially on roads with free flowing traffic and speeds above 50 km/h. But powertrain noise also has to be reduced somewhat to fulfil new limits. This is especially the case for vans, lorries, HGVs and buses.
For roads with intermittent traffic, which affect a substantial part of the population, a major part of the noise reduction has to be achieved on powertrain noise for all vehicle types.

Annual growth in road traffic is projected at approximately 1,6 % for cars, 0,6 % for buses and coaches and 1,2 % for road freight (vans, lorries and HGVs). In 10 years, L_{DEN} and L_{night} levels increase by around 0,6 dB for all road types. This increase in traffic volume can diminish the gained noise reduction and the associated benefits. Over a 20 year period, without any countermeasures, the reductions in L_{DEN} and L_{night} could be diminished by 1,2 dB, resulting in only 1,3 dB for option 4 and 2,7 dB for option 5.

Single event levels remain unchanged for options 1 and 3, and may increase by around 1-2,8 dB for option 2. For option 4 they would reduce by 3,2 dB for cars and vans, 3 dB for buses and 2 dB for lorries and HGVs. For options 5, they would reduce 4,6 dB for cars, 4,4 dB for vans, 4 dB for buses, and 3 dB for lorries and HGVs.

The social impact in terms of numbers of highly annoyed people and highly sleep disturbed people is significant. For the current situation (option 1) an estimated 55 million people are highly annoyed by road traffic and 27 million are highly sleep disturbed. These numbers are reduced to 44/22 million for option 4 and 41/22 million for option 5. Option 2 leads to an increase of 9/3 million. The reductions for options 4 and 5 will also lead to an increased quality of life for millions of people, with reduced stress levels and improvement in work, home and recreational environments. However, due to projected traffic growth over a period of 10 years, numbers of highly annoyed and highly sleep disturbed people grow by 3 million and 1 million respectively.

The impact on health can be quantified by Disability Adjusted Life Years (DALYs), which takes into account lost productive time and actual lost life years due to various types of disease. Annual numbers of DALYs due to current noise levels are estimated at upto 6,5 million related to annoyance and 3 million related to sleep disturbance. It is estimated that options 4 and 5 reduce the number of DALYs by 0,1-1,4 million for option 4 and by 0,1-1,6 million for option 5.

The economic impact consists of benefits to society due to reduced traffic noise and costs for the vehicle industry due to reducing noise levels of vehicles, in particular the powertrain noise, as tyre noise will be reduced due to the tyre directive.

The impact on the vehicle industry consists primarily of additional development and production costs due to extra reduction of powertrain noise on vehicles. These costs are lower per vehicle unit for cars and vans than for heavy vehicles such as lorries, HGVs and buses.

The accumulated costs amount to 5 billion Euros for option 4 and 7,7 billion Euros for option 5. These costs are incurred over a development and production cycle of 3+7 years and consist mainly of additional production costs which are no longer incurred after 10 years.

The accumulated benefits for society consist of valuation of noise reduction, healthcare savings and savings on noise abatement on road infrastructure and dwellings. By far the largest benefits are due to hedonic pricing related to perceived value of noise reduction, followed to a lesser extent by healthcare savings and relatively smaller savings on noise abatement costs.

Together, these benefits are in the order of 101 billion Euros for option 4 and 120 billion Euros for option 5 over the period 2010-2030. The benefits outweigh the costs for industry by a factor 20,1 for option 4 and a factor 15,7 for option 5. The benefits increase gradually and are sustained over 20 years, whereas the costs for industry occur from 2-3 years before and upto 7 years after the limits are changed. The environmental and social benefits may be reduced by half if traffic growth continues at current rates.

8 Evaluation and appreciation of the new test method

8.1 Inquiry among type approval authorities

Until now the new method B has mainly been used within the framework of the monitoring procedure called for in UN-ECE Regulation 51- Addendum 50 – Revision 1 References [2]. The most extensive experience with the new method is therefore available at the type approval authorities that were commissioned with the task of drafting and submission of the test reports according to method B. A small inquiry was held to obtain recent and unbiased information about the strengths and weaknesses of the method. A number of type approval authorities in EU member states that had submitted a significant number of reports for the database were approached and asked to respond to a small questionnaire, given below. The answers received were used in the evaluation of method B, which is discussed in the following sections.

Questions for Type Approval Authorities

1. How are your experiences with the new test method B (Regulation 51 – Addendum 50 – Revision 1 – Annex 10) with respect to:
   a. Manageability of test parameters (speed, acceleration, engine speed);
   b. Occurrence of abnormal behaviour of the vehicle or the noise production during the test;
   c. Representativeness of the test parameters in comparison to the engine and vehicle conditions during normal (urban) driving;
   d. Representativeness of the noise test results in comparison to other engine and vehicle conditions (off-cycle emissions)
   e. Complexity of the method in comparison to the current test method A;
   f. Efficiency of the method in comparison to the current test method A;
   g. Specific problems.
2. Most vehicles are tuned and adapted to the current test method A and the noise emission limit values currently in force. For method B such adaptations have not yet occurred. What is your estimate [in dB(A)] of the effect of such adaptations?
3. For test method B other requirements are specified for the use of tyres during the test than for method A.
   a. Do you consider the new formulation of the requirements effective in order to prevent the use of inappropriate tyres during the test?
   b. Have you experienced problems during the testing according to method B with abnormal or non-representative noise production of tyres (especially for trucks)?
4. What is the cost of testing per vehicle according to method A and to method B?
5. Can you give any other information that may be relevant to our investigation?

8.2 Complexity and operability of the new method B compared to the old method A

As discussed in Chapter 3, the test procedure for light vehicles (M1, N1 and N2 < 3,5t) in method B includes one or two WOT (Wide Open Throttle) acceleration tests and one or two constant speed tests. In comparison to test method A, which consists of one WOT test only, this means a considerable increase of the complexity of the method. The complexity of method B is assessed three times higher than method A. Furthermore the procedure for the choice of gear ratio and the determination of the approach speed,

which is related to the achievable acceleration, require more attention than necessary in method A. The more intricate nature of the test procedure makes it less obvious whether mistakes have been made or not. Also the actual precision of the test is more dependent on the ability of the test driver. Depending on the type of measuring equipment (fully integrated or separate systems) the management of the test process may be time-consuming. Apart from that, the method is reproducible and manageable and no specific problems concerning the execution of the tests have been reported.
As test method B produces lower noise emission results than method A it is more sensitive to environmental parameters, e.g. background noise, ambient air temperature, relative humidity and atmospheric pressure, wind speed and direction. This greater sensitivity may influence the reproducibility of the test results.

A specific ambiguity of the test instructions was reported with respect to the choice of gear ratio in the case of automatic transmissions. If an automatic transmission has the possibility to lock the gear ratio it is not prescribed in a clear way whether the vehicle in question should be tested in one or two specific locked gear ratios or in the 'Drive'-position of the transmission with unlocked gears. According to the current instructions both procedures seem permissible. As the test results for the two procedures may be significantly different a revision of the instructions for the gear ratio selection is recommended.

For buses (vehicle categories M2 and M3) the test method B is no more complex than test method A. For heavy vehicles (categories N2 and N3) method B is more complex than method A due to the requirements for the loading of the vehicles. On the other hand the number of gears to be used in the test in method B is smaller than in method A.

It was reported that the instructions for loading of heavy vehicles during the test to reach the required test mass are not completely clear and unambiguous. It is recommended to revise the loading requirements and to specify in a more direct way how the load should be distributed over the axles in the case of one, two or more rear axles.

8.3 Representativeness of test method B

The test conditions of method B are considered more representative for average urban driving conditions than method A, which is more aimed at measuring the higher noise emission levels. In some cases (e.g. light sports cars) the reference acceleration of the vehicle in method B may reach such a value that a gear must be chosen that is not representative for normal driving at the required speed.

Currently the test conditions of test B also seem to be a representative measure for the noise emission under other operating conditions, because there is no sign that vehicles have been engineered to comply with the test conditions. This may change once the test method B has been put into force.

Although the test conditions in method B (vehicle speed, choice of gears, acceleration and engine speed) may be considered representative for average urban driving conditions, they only cover a small part of all possible operating conditions of the vehicle. This is in particular the case for powerful passenger cars with a high dynamic range and a high potential of acceleration and related engine speeds. Therefore off-cycle provisions will be necessary to safeguard the representativeness of the method B test conditions for the full range of possible operating conditions. The objectives and requirements of these off-cycle provisions are discussed in Chapter 9.

One of the type approval authorities reported an experience with some experiments concerning modifications to a vehicle. In this vehicle the intermediate exhaust damper was omitted, which should lead to an increase of the noise emission. This was confirmed by stationary test results. Nevertheless the pass-by test result with method B was lower than the original test result for homologation measured with method A. This example illustrates that method B in many cases operates at very low engine speeds. Therefore the method is not always representative for noise emission mechanisms, that are only apparent at higher engine speeds, such as exhaust noise.

In order to improve the interaction between the basic type approval test and the off-cycle provisions it is advisable to delete from test method B the requirement that the acceleration during the test shall not exceed 2 m/s^2. In this way also for vehicles with a high acceleration potential, higher engine speeds will be applied during the test than according to the current description of method B. In many cases two gear-ratios will be used for these cars instead of only one gear-ratio with an unrealistically low engine speed, as is the case for the current description.

8.4 Consequences of implementation of test method B for Japanese Kei-cars

In Japan special sub-categories of small, low powered vehicles exist within the passenger car category (M1) and within the van and pick-up truck category N1. These vehicles are indicated as Kei-cars and they have to fulfil the following requirements:

- Vehicle length: < 3.40 m
- Vehicle width : < 1.48 m
- Vehicle height: < 2.00 m
- Engine displacement : < 660 cc

And for trucks:

- Payload: 350kg

On request of the Japanese Automobile Standards Internationalization Center (JASIC) the consequences of the implementation of test method B for these special sub-categories of vehicles were investigated. Basis for the investigation was a data set of 20 Kei passenger cars and 16 Kei vans and trucks. Although these vehicles are not available on the European market the test reports according to methods A and B were submitted by JASIC for comparison with the other available vehicle data.
The averages of the Kei car test results are given in Table 36

Table 36 - Average test results of Japanese M1 and N1 Kei cars

Vehicle subcategory	Number of test results		Average test result method A [dB(A)]		Average test result method B [dB(A)]		Difference B-A [dB(A)]	
M1 – Kei-cars	20		69,8		70,4		0,6	
M1 General	652		72,1		70,0		-2,1	
N1 – Kei-cars	16		72,4		72,1		- 0,4	
N1 General	52		73,7		72,0		-1,7	
	Manual	Automatic	Manual	Automatic	Manual	Automatic	Manual	Automatic
M1 – Kei-cars	4	16	71,1	69,5	68,7	70,9	-2,4	+1,4
M1 General	434	218	72,4	71,4	69,9	70,3	-2,5	-1,1
N1 – Kei-cars	4	12	73,2	72,2	72,3	72,0	-0,8	-0,2
N1 General	42	10	74,1	72,3	71,8	72,9	-2,3	+0,6

The average test results of test method B for these vehicles are very similar to the average test results for the total data set of M1 and N1 vehicles (see Table 36). However, the average results for test method A deviate from the general averages by - 2,3 dB(A) for the M1 Kei cars and by – 1,3 dB(A) for the N1 Kei car vans and trucks (see Table 36). Therefore also the differences between B and A deviate. As a consequence of the lower results of these vehicles in test method A also the regression lines giving the results of test B as a function of the results of test A show a different pattern (see Figure 27).

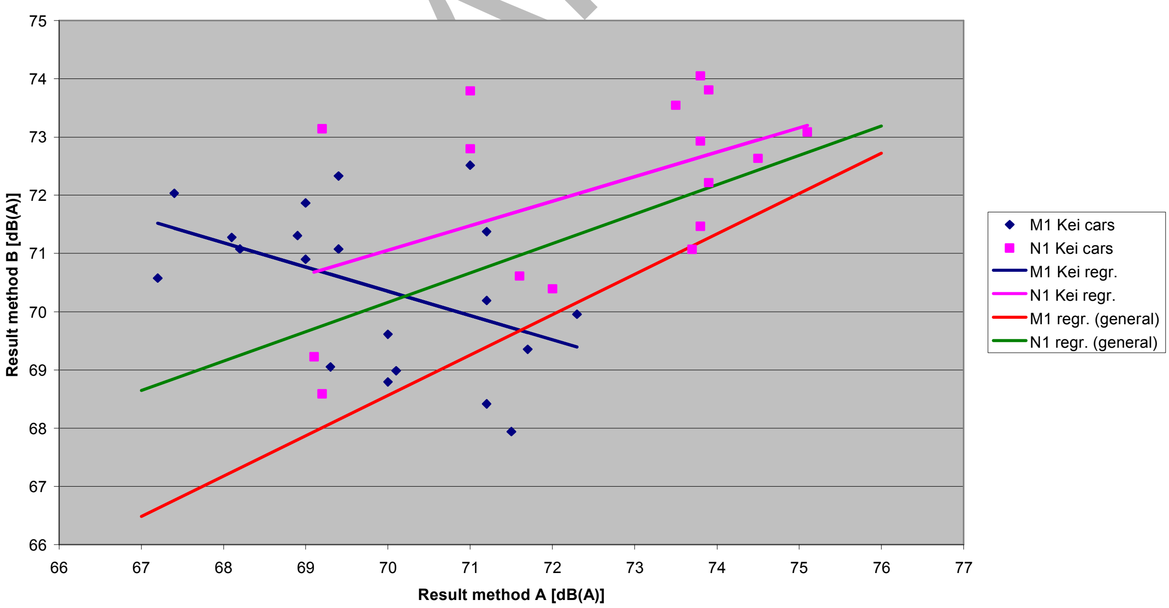


Figure 27 – Results of test method B as a function of the results of test method A for M1 and N1 Kei cars in comparison to the general regression lines for M1 and N1 vehicles.

For the M1 Kei cars the slope of the regression line (dark blue) is negative while the general M1 regression line (red) has a positive slope. For the N1 Kei cars the slope of the regression line (pink) is fairly similar to the slope for the general N1 regression line (green), but the Kei car N1 line is shifted upward with 0,5 – 1 dB(A). The correlation

between the test B and test A results for both categories of Kei cars is rather low (correlation coefficients: -0,45 and 0, 51).
The negative slope of the M1 Kei car regression line might be caused by the fact that the majority of the M1 Kei cars (80%) has an automatic gearbox and has been tested under method B in the full automatic position of the gear-selector. Probably this procedure results in relatively higher engine speeds than when the gearbox is locked in one of the gears, as is allowed according to the method B instructions. It is plausible that this fact is the main reason for the slightly deviant relationship between the test A and test B results. Otherwise the results of the M1 Kei cars for test A and B are fully within the range of the results of the other M1 cars. If the results of the M1 Kei cars are compared with the proposed equivalent limit value of 72 dB(A) for test method B according to Policy option 3 only 1 out of 20 vehicles (= 5 %) would not comply with this requirement.
For the N1 Kei vans and trucks 75 % of the vehicles has an automatic gearbox and is tested under method B in the full automatic position of the gear selector. For these vehicles the results of test B are slightly higher (0,5 – 1 dB(A)) than could be expected according to the general regression line for N1 vehicles. If the results of the N1 Kei vans and trucks are compared with the proposed equivalent limit value of 73 dB(A) according to Policy option 3 for test method B 4 out of 16 vehicles (= 25 %) would not comply with this requirement.

In the lower part of Table 36 the data are divided in Manual and Automatic gearboxes. This shows that all differences between Kei-cars and other vehicles (of the same category) are limited and in view of the small number of Kei-cars involved not significant.

Summarising the analysis given above, it may be concluded that the Kei cars do not deviate fundamentally from the other M1 and N1 vehicles in the database. Most of the differences are probably caused by the large percentage of automatic gear boxes in comparison with the percentages for the vehicles in the general database (M1: 34 % ; N1: 19%). In view of these specific characteristics of the Kei car data set there is no evidence that test method B would not be suitable or representative for these sub-categories of vehicles.
Also because the vehicles in question are not available on the European market there is no reason to modify the proposed limit values for these sub-categories.

8.5 Balance between powertrain noise and tyre-road noise

The test result L_{urban} for light vehicles (M1, M1G, N1, N1G and M2 < 3,5 t) in method B is computed as a weighted average between the result of the WOT (Wide Open Throttle) test, $L_{wot\ rep}$, and the result of the constant speed test, $L_{crs\ rep}$. The average and the range of the difference between these partial results is given in Table 37. The average difference is between 1,6 and 3 dB(A), although the spread of this difference is large, especially for the passenger cars. Taking into account that also the WOT partial test result is a mix of power train noise and rolling noise of tyres and that the constant speed test result is largely dominated by tyre rolling noise one may infer that the final test result L_{urban} will be strongly influenced by tyre rolling noise.
In Appendix E a detailed estimative computation is presented of the power train and rolling noise contributions to the WOT test result and the constant speed test result. The computation is based on two assumptions:

- The power train noise emission during the constant speed test is on average 4 dB(A) lower than the rolling noise emission of the tyres;
- The rolling noise emission during the WOT test at 50 km/h is equal to the rolling noise emission during the constant speed test at 50 km/h.

In the Table below also the difference between the estimated power train noise and the rolling noise during the WOT test is given. For most of the vehicle categories the power train noise during the WOT test is on average approximately 2 dB(A) higher than the rolling noise. This implies that the WOT test result is 4,1 dB(A) higher than the rolling noise. From this fact it can be computed that the final result L_{urban} is approximately 3,2 dB(A) higher than the rolling noise contribution, or in other words, that the tyre rolling noise contributes 48 % to the final test result. This substantiates the statement made above, that the test result L_{urban} is strongly influenced by tyre rolling noise.

Table 37 - Difference between the partial test results of the WOT test and the constant speed test in method B and the difference between estimated power train noise and rolling noise for light vehicles

Vehicle category	$L_{wot\ rep} - L_{crs\ rep}$			$L_{PT\ wot} - L_{roll\ wot}$
	Average	Minimum	Maximum	
M1	2,7	-0,2	18,3	1,7
M1G	3,0	0,6	9,2	2,3
M2 < 3,5 t	2,7	1,9	3,7	2,0
N1	2,3	0,1	4,8	1,2
N1G	2,7	2,2	3,2	2,1
N2	1,6	0,6	2,6	0,1

This approximately 50-50 % balance between power train noise and tyre rolling noise is an important factor for the representativeness of the test result of method B for the noise emission of vehicles under normal traffic conditions. However, this same factor makes the test result less representative for conditions with higher noise emission, e.g. during fast acceleration, because the test result is not very sensitive for power train noise differences. Therefore additional off-cycle emission provisions will be needed to cover this issue.

8.6 Optimisation of vehicles to the test method

The current test method A has been in force for a very long period. Vehicle manufacturers have learnt to take the test conditions and the type approval requirements into account in the design process of the vehicles. Therefore under the current test procedure there are no vehicles that do not comply with the applicable limit values. This adaptation or optimisation to the test method has not yet taken place for test method B, which is new and was applied on a large scale for the first time during the monitoring period. One of the results of this lack of optimisation is that the results of test method B for some vehicles do not comply with the current limit values. This seems contradictory to the fact that the average test results of method B for most of the vehicle categories are lower than the results of method A. The lack of optimisation can be seen when comparing the histograms for methods A and B in Figure 9, Figure 10 and Figure 11. The histograms for method A cut off sharply at the limit values, while the histograms for method B show a more natural tapering off to higher sound emission levels.
From the type approval authorities no specific information on this topic was received. It was mentioned that there was no evidence of design adaptations to comply with the test. If a vehicle were designed to comply with test method A this design would probably

also be favourable for test method B. A suspicion was expressed that for a small number of ‘exotic’ vehicles specific adaptations (‘defeat devices’) are being used, although no direct proof of such facts was presented.

In particular for passenger cars (M1 vehicles) an estimate can be given for the possible effect of design optimisations. Based on the differences between the histograms for test methods A and B for these vehicles it may be assumed that after some time the results of test method B will show a similar high end cut off as the results of test method A. The highest values will then be 72 or 73 dB(A). The emission values of approximately 10 – 15 % of the vehicles will become lower than the current test results. The possible reduction may vary between 1 and 7 dB(A).

8.7 Control of the selection of test tyres

Under the current test specifications according to method A the mounting of tyres for the test is not regulated very strictly. As a result the mounting of tyres other than traction tyres on the driving axles of heavy trucks has become rather common. This may lead to ‘improper’ test results that are lower than they actually should be.
In the specification of test method B the requirement was added that the tyres “shall be representative for the axle”. The question is whether this formulation is effective and sufficient and will prevent the mounting of non-representative tyres.

From the type approval authorities the response was that the formulation is considered to be sufficient, but that it is difficult to control, both for method A and B. The question was raised how large the influence of the tyres on the test result actually is. Assuming a WOT test of a truck under full or nearly full power it is likely that the contribution of rolling noise to the test result is relatively small. This may imply that the choice of test tyres is not of decisive importance for the compliance with the type approval requirements.

From the data files in the Circa database it can be concluded that in most cases the tyres mounted on heavy vehicles for test B are different than for test A. Although the actual characteristics of the tyre types mentioned in the files were not verified, this fact indicates that for test B tyres were mounted that were representative for the axle. For N3 vehicles the average result of test B was 1,2 dB(A) higher than for test A; for N3G vehicles, with presumably more pronounced traction tyres, the average result was 0,6 dB(A) higher. Although other test parameters also play a role in this simple comparison, it may be inferred that the choice of the test tyres does not have a major influence on the test results.

This simple analysis can be supplemented with more detailed data, because one truck manufacturer submitted an interesting selection of test results, in which each tested truck or coach was measured two or three times with different types of tyres mounted on the drive axle. These tyre types were: a steering tyre, a traction tyre of the same brand and in some cases also a traction tyre of a different brand. The tyre size was in all cases 315/80 R22. The data set included 17 N3 trucks, 8 N3G off-road trucks and 1 coach.

From the comparison of these data it appeared that the **average difference** between the test results with **traction tyres** and with **steering tyres** is **0,6 dB(A)** for the traction tyres of the same brand and **1,0 dB(A)** for the traction tyres of the other brand. The largest recorded difference was 1,7 dB(A).

These findings confirm the conclusion that the choice of tyres on the drive axle of trucks does not have a major influence on the test result.
Recently some concern was raised during the discussions in the UNECE – GRB about the supposedly occurring high noise emission levels of truck traction tyres under torque [40] [41]; overall noise emission test results of 80 – 86 dB(A) were reported, with the suggestion that these values were determined to a large degree by the rolling noise emission of the traction tyres under torque.
In view of the figures obtained from the tyre data comparison discussed above, this concern can be considered unfounded. Furthermore, there is no evidence that the noise generation of traction tyres during the type approval test according to method B is abnormal or not representative for the normal noise production of heavy vehicles during acceleration in urban areas.

Based on all these considerations, the formulation of the requirement in test method B, that the tyres used for the test shall be representative for the axle, seems to be adequate. The only concern may be that the type approval authorities find this requirement difficult to control. Therefore it might be advisable that the European Tyre and Rim Technical Organisation (ETRTO) would publish on its web-site a regularly updated overview of available truck tyres in the different tyres classes and categories, so that the type approval authorities can easily verify, based on the tyre brand and type indication, whether the tyres mounted on the drive axle(s) during the test comply with the requirement.

9 Off-cycle provisions

The test cycles of both method A and B only cover a (very) limited part of the possible operating conditions of motor vehicles in real traffic. Whereas the WOT test of method A is based on a worst case scenario for the powertrain part of the noise emission, in method B a mixture of both powertrain and rolling noise is covered. However, it still encompasses only a conditioned and limited range of the possible environmentally relevant operating conditions that can occur in (urban) traffic. As a result the noise emission of motor vehicles can still be optimised for the test cycle relatively easily, which can result in a rather limited effect of noise emission regulations on the actual road traffic noise in urban areas. This issue can be tackled with so-called “off-cycle provisions”.

9.1 General goals for off-cycle provisions

In general off-cycle provisions are preventive requirements intended to:

- Cover operating conditions that are not covered by the official test cycle, i.e. the type approval test condition (in this case method A and B). It should be ensured that the noise emission of a certain vehicle under these conditions does not result in a significantly higher level than could be expected from:
    - The noise emission measured during the regular type approval test.
    - The normal physical behaviour of increasing noise versus increasing (engine) speed.
- Minimise cycle beating possibilities. This means that it should be prevented that when a vehicle ‘recognises’ a unique condition as in the current type approval, the noise emission during this test cycle is substantially lower than in other conditions, which can be incorporated in an off-cycle provision or additional emission test (see Figure 28).
- Support law enforcement and in-use compliance. In the off-cycle provisions a test method with accompanying limit value could be included, which can be carried out rather easily by police or other authorised bodies. Examples of such test methods are a stationary noise emission test (similar test already included in the current type approval regulation, but without limit value) and for example a test that regulates the maximum noise emission under any possible operation condition, i.e. an absolute maximum noise limit.
- Support conformity of production (COP) tests. It could simplify testing for notified bodies, if for example an easy to perform off-cycle COP test option were included in the type approval regulation.

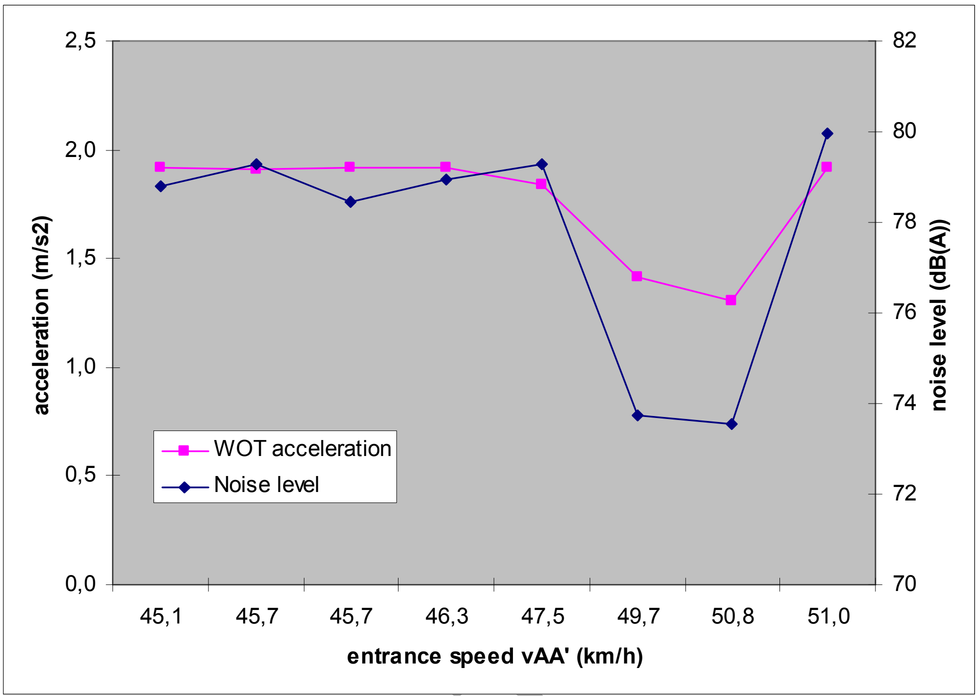


Figure 28 - Example of a vehicle with cycle beating. The vehicle recognizes the test cycle (method A): if the entrance speed is 50 km/h ± 1 km/h the acceleration drops by 30% and the noise level drops by 6 dB(A). Data from ASEP dBase vehicle 200-13.

9.2 Evaluation of proposals for GRB ASEP method

In the UNECE – GRB (Working Group on Noise – WP29) it was already noticed that method B will result in a shift from pure powertrain noise emission to a mixture of both powertrain and rolling noise, with perhaps even an emphasis on rolling noise. One of the main reasons for this is the relatively low engine speed during the test and as a result low powertrain/exhaust noise.
To compensate for this an Informal Group (GRBIG) was formed within the GRB to develop a so-called Additional Sound Emission Provision (ASEP). This provision should contain a test method that covers the power train noise in particular, which dominates the overall noise emission during moderate to strong acceleration in urban situations. The ASEP only applies to M1 and N1 vehicles with an internal combustion engine.

Currently two proposals are being worked out in more detail within the GRBIG: one suggested by the GRBIG (method 1) and an alternative suggested by the Netherlands (method 2) [27]. Briefly these methods are as follows:

- The starting point of both methods is the test result of test method B: The WOT noise level $L_{WOT,i}$ of method B is used as an anchor point for the expected noise emission in a linear (regression) function of the engine speed n in a particular gear ratio i.
- For the method 1 proposal the ASEP limit curve is determined from four elements:
    - The "anchor point" is determined by the noise level L_{anchor} and engine speed n_{anchor} (both equal to the method B L_{WOT} and n_{WOT}).

  - o The "slope" of this curve is calculated by linear regression analysis from four noise measurements at four equidistant engine speeds. The slope is maximised to a certain value.
  - o The "margin" (a constant value to allow for small resonances and random variations).
  - o The "bonus for silent vehicles" (a constant value determined by the difference between the noise limit and measured L_{urban} of method B).

  The maximum slope, the value of the margin and the application of the bonus are all still to be fine tuned and agreed in GRB. Proposals have been made by OICA and various contracting parties in the IG.
  The 4 measured ASEP noise levels for each gear should remain below the limit curve. Finally, 2 extra, randomly chosen measurement points can be added, for which the noise level should also remain below the limit curve.
  Furthermore, as an attachment, the German KBA proposed to add an extra limit value called L_{ref}, to ensure that the vehicles cannot become significantly noisier than in the current method A acceleration test cycle result [28]..
- In the method 2 proposal the noise limit curve above the anchor point is a direct linear connection between L_{anchor} and a predefined maximum noise level at a not-to-exceed (NTE) point. This NTE point is a fixed number Y above the limit of Method B and the engine speed at this point is determined by a statistical function as given in chapter 2.3 of Annex 10 in [27]. In the current proposal Y is 8 dB(A) and L_{anchor} is equal to L_{WOT} from method B plus a margin of 2 dB(A) plus the difference between the noise limit value and measured L_{urban} of method B. The measured noise level at any engine speed should remain below the noise limit curve. This is tested at 4 randomly chosen measurement points.

To analyse the impact of both proposals, the GRB informal group has made a database with measurement data. The PMR distribution of the vehicles in this database is comparable to the PMR distribution of the Circa database that is currently under investigation.
In the database a distinction can be made between so-called 'vehicles of no concern', 'border case vehicles' and 'vehicles of concern', from which the latter 2 have the potential to become (much) too noisy without off-cycle provision requirements. After studying both proposals, the following conclusions can be drawn:
- The stringency of the two proposals very much depends on the coefficients X,Y and Z for slope, edging, delta and margin. By adjusting these coefficients both methods can be tuned from liberal to stringent.
- The design and nature of the two methods is completely different
  - o Method 1 is primarily designed to investigate the linearity of the noise curve and not to limit the absolute noise emission. Within restrictions the system is self-adjusting: a steeper slope can be allowed as long as it is linear. This self-adjusting system is bounded by a maximum allowable slope, from which the value is yet to be agreed. As only a maximum slope in dB/rpm is set, the absolute noise level could rise to very high levels (> 100 dB) if the engine would have a very high rated engine speed.
  - o Method 2 is primarily designed to set a noise limit additional to annex 3 (method B). Within the ASEP control range the noise emission is allowed to be higher than the annex 3 limit, but only upto the defined limit curve. Method 2 is not designed to check the linearity of the noise curve.
- Method 1 may lead to higher noise emissions, as manufacturers may have to increase the currently low noise emissions in the low or mid engine speed range, in

order to shift the self-adjusting limit curve to higher levels (steeper slope) and therefore legalise existing high noise levels in the high engine speed range.

- The limit curve of ASEP method 2 is available in an earlier design phase than the limit of method 1. This is because the limit curve of method 2 is mainly independent from measurements, while method 1 needs measurements from a real vehicle before any limit curve can be determined.
- Method 2 also reduces the possibility to optimise the vehicle for the test method more effectively, since the noise limit curve is not derived from measured noise values as is the case in method 1.
- An important conclusion is that method 2 distinguishes much more between vehicles of no concern and vehicles of concern; vehicles that are currently (much) too noisy in an off-cycle situation are clearly identified by method 2. Method 1 combined with the ASEP limit values proposed by OICA does not make this distinction at all, which is unacceptable from an environmental point of view. Similar conclusions are drawn by other experts [29], [30].
- A disadvantage of method 2 is found for vehicles with high rated engine speed. With the currently proposed NTE point with an equal allowed noise level increment (fixed number Y above L_{anchor}) for every vehicle in method 2, the vehicles with a high PMR and high possible engine speeds are put at a disadvantage too much in this method. Due to this fixed increment the slope of the maximum allowed noise as function of the engine speed is much lower for high PMR vehicles: the slope of the curve is the increment Y divided by the engine speed range, from which the latter can become large for high PMR vehicles. In many cases for high PMR vehicles the slope of the limit curve of method 2 is 2 or 3 dB(A)/1000rpm, whereas for an 'average' vehicle this is already estimated to be around 5 dB(A)/1000rpm in case of moderate acceleration.
- On the other hand, this inconsistency is also due to the low target acceleration and thus the low engine speed in the WOT test of method B: in general the higher the PMR, the lower the engine speed at the anchor point. This is a fundamental inadequacy of method B.
- This is even more pronounced as the WOT acceleration in method B is set to a maximum of 2 m/s^2. The limitation of the acceleration in method B to 2 m/s^2 has large implications on ASEP, since the anchor point is taken from method B. There is only marginal acoustical effect of this limitation in method B. It results in single gear tests in high gears at low engine speeds for high-powered vehicles. The effect of the low engine speeds is largely compensated in method B by the partial load factor k_p. However, in the ASEP there is no compensation and the low engine speeds of method B will result in ASEP anchor points with unbalanced low engine speeds. For ASEP method 1 this leads to a shift in the total limit curve and therefore will result in a higher limit curve. For ASEP method 2 this leads to a shift only in the anchor point (as the NTE point is fixed) and therefore in an artificially flat limit curve.
- Both methods do not falsely disqualify most of the vehicles of no concern. However, in some cases method 1 is more liberal than method 2 and thus provides a margin for extra noise emission. Therefore the German KBA proposed an extra limit value L_{ref}. In fact this is a reparation of a basic fault of the method, which is not an efficient way to achieve and repair the original goals for an off-cycle provision.
- A major drawback of method 1 as it stands now, is that there is no NTE point i.e. no absolute maximally allowed noise level. As a result theoretically the noise

emission can become extremely high at very high engine speeds, which are beyond the scope of the current development of the method.

- As method 1 is based on a maximum slope in dB/rpm, it is more friendly for vehicles with high rated engine speeds compared to vehicles with the same power, but lower engine speed and higher torque. As such high torque engines may include turbo charged engines, which are currently becoming rapidly more popular (‘downsizing’), these designs may have a disadvantage in method 1.
- As turbo engines may also have typically non-flat torque curves, their noise curve may also be less linear than traditional, natural aspirated engines. This is also a disadvantage of method 1, which focuses on linearity mainly.
- Both methods are based on a noise limit as function of engine speed and therefore only suited for vehicles with an internal combustion engine. Hybrid or other alternatively powered vehicles cannot be incorporated in the current proposals. Therefore in future, a test method that does not directly depend on the engine speed, would be more desirable. An improved ASEP method should evaluate the noise emission as function of propulsion power in terms of vehicle acceleration and vehicle speed, just as in method B.
- The boundary conditions of the ASEP control range, which is applicable to both ASEP methods, are too restrictive. It should be noted that these boundaries strongly reduce the actual range in which high-powered vehicles will be tested in ASEP.
    - RPM boundary curve as function of PMR: For high-powered vehicles this boundary comes as low as 60% of rated engine speed. This means that for high-powered vehicles 40% of the engine map is not covered by ASEP.
    - Vehicle speed ≤ 80 km/h: this boundary is set for practical reasons, because some test tracks may be too short to test at higher speeds. This may however be a temporary or a local problem. It restricts at least the area of valid tests to a speed which is significantly lower than the maximum speed in most countries.
    - Acceleration ≤ 4 m/s^2: vehicles with PMR> 150 kW/t are able to exceed this boundary in 2nd gear [42]. This means that all those vehicles can be tested only at low rpm in 3rd gear. In combination with a maximum vehicle speed of 80 km/h this leads to engine speeds not higher than 50% of the rated engine speed. Moreover, gear dependent sound design measures can be applied legally in 2nd gear without violating the ASEP demands.

  The proposed boundaries of the ASEP control range may act as a form of extra allowance for high performance vehicles, because a significant part of the operating conditions of such vehicles is not covered in the proposed ASEP methods.
- Both methods fail to cover an important field of operating conditions: the partial throttle noise emission. According to generally applicable physical laws, partial load emissions should always be less than WOT-emissions. Nevertheless the proposed test methods and limits for ASEP apply to WOT accelerations only. It would be relatively easy to design a vehicle with two different distinct sound emission modes, one for WOT type approval conditions and another one for all other (partial) load conditions in real traffic. Such a design would not be illegal, but it would result in noise emissions that might exceed the future ASEP limits. Therefore, it is recommended to make the ASEP regulation valid for all operating conditions in the ASEP control range, including partial throttle acceleration. Although it may be difficult to test partial load conditions in a reproducible way, this does not have to be a problem for ASEP: the ASEP limit curve can be based on WOT conditions, while every individual partial throttle measurement can be checked for compliance with this WOT limit. As soon as the noise emission during

any partial throttle operating condition can be demonstrated to exceed the ASEP limits, this can be considered as a violation of the ASEP regulation.

- Both methods have focussed on OEM vehicles only as they are intended to be included in UNECE Regulation 51. Directive 70/157 however includes demands on replace exhaust systems. Both ASEP methods can be easily expanded to replacement exhaust systems on the basis of a back-to-back comparison with an OEM system.

9.3 Discussion of other possible methods for off-cycle provisions

From the authors' point of view, the basic assumptions of both methods for ASEP are not optimal: a test with the noise level based on only on the engine speed has some major disadvantages, as stated above. Therefore it would be more desirable to have a test with a similar basis as method B: a prescribed acceleration, irrespective of the required engine speed. Furthermore an off-cycle test should cover environmentally relevant operating conditions, which can be done with a noise emission limit curve as function of acceleration and vehicle speed. Such a test procedure was already proposed by two parties:

- The Netherlands defined in 2007 a noise emission limit curve as function of acceleration and speed and a WOT test that should ensure that the noise level remains below the curve [31]. This proposal was withdrawn due to some practical issues and the lack of official support within the GRBIG.
- A similar concept was recently presented by the Chairman of ISO WG42. In this proposal ASEP measurements are evaluated on the base of L_{urban} from method B [32]. This concept was never officially launched as an alternative, but may be worth studying in more detail.

The most important advantages of these test procedures are: hybrid and other alternatively powered vehicles can be incorporated, vehicles with a high PMR are treated correctly and it can also be used for law enforcement and in-use compliance. A disadvantage of the test procedure as it stands now is that the noise emission of vehicles with a non-lockable automatic gearbox can become disproportionally high for a relatively low acceleration, when it automatically changes gear in the case of WOT. However, there should be an (easy) way to solve this problem.

There are many other possible methods for off-cycle provisions. Some of them are discussed here:

- First of all the current method A could be used. It is a relatively easy to perform and well known test method, that covers powertrain noise for most of the vehicles. However, for many high PMR vehicles also in the method A test the engines speeds are relatively low and thus only partially covered. One reason for this is that they are allowed to be tested in only the 3rd gear. Besides that, it is not a real off-cycle provision that covers all kinds of environmentally relevant operating conditions. Secondly, cycle beating remains simple. This is underpinned by the GRBIG ASEP database, where some high-powered vehicles have a clear dip in the noise emission around the method A working point.
- An absolute maximum for the noise emission limit could be regulated. Then the noise emission of a vehicle should remain below this limit for any given situation and operating condition. On the one hand this is a rather simple and straightforward method. However, on the other hand there are many problems for practical implementation of this method for e.g. passenger cars. Some issues are: the

dynamic range of maximum noise emission is very large for passenger cars. So what should the limit value be? What are the boundary conditions for such a test method? How reproducible is the test? Besides that, first of all an acceptable vehicle lifetime effect on the noise emission should be investigated.
For heavy vehicles (N3) such a test is more practically feasible, because there the dynamic range in noise emission is much smaller; only a few dB(A) for new vehicles. Therefore for this vehicle category this regulation already exists in some States in the USA: maximum 87 dB(A) at 15m under any circumstance (normal driving, uphill acceleration, etc.) on any type of pavement. An example is given in Table 38.

Table 38 - Maximum Noise Emission Levels as Required by EPA for In-Use Medium and Heavy Trucks with GVWR Over 10,000 pounds Engaged in Interstate Commerce

Effective Date	Speed	Maximum Noise Level 50 feet from Centerline of Travel
January 8, 1986	< 35 mph	83 dBA
January 8, 1986	> 35 mph	87 dBA
January 8, 1986	Stationary	85 dBA

- A more radical change to the test method would be to replace the pass-by noise emission test methods with one or a few working points by a comprehensive test cycle that incorporates many different operating conditions, similar to the test cycles for CO_2 and exhaust emissions. This could really cover all the environmentally relevant operating conditions that can occur in real traffic. With the test both a maximum noise level L_{max} and an equivalent noise level L_{eq} could be determined, which is more in line with noise immission and noise annoyance regulations.
  Such a test cycle would have to be performed on an indoor or outdoor test bench. Recently within ISO a so-called New Work Item Proposal (NWIP) has been approved with the title ‘Test Procedure to Achieve an Acoustical Correlation between Exterior Noise Testing in a Free Field Anechoic Test Chamber and Real Outdoor Testing’ [33]. The main goal of this NWIP is to make it possible to perform noise type approval tests, which are carried out on an outdoor test track until now, in an indoor test facility. This is fully in line with the test cycle proposal as stated above. However, such an indoor test method is not available yet.

9.4 Proposal for improvement of off-cycle provisions

From the technical point of view the authors prefer an ASEP method which will evaluate the noise emission on the base of vehicle speed and acceleration. Two preliminary proposals are available. Current deficiencies can be solved in a technical working group. It is recognised that the further development work of an optimised ASEP method will require more development time. This should not interfere with the time schedule for introduction of test method B and the related stricter limit values. The optimisation of the ASEP method may run in parallel to the introduction of the type approval test method and may be put into force one or two years after the introduction of a new type approval regulation.

Considering only the 2 current 'official' proposals within GRB, it shall be noted that both proposals have some deficiencies and could be improved. The most important issue, the stringency, can be tuned for both methods. Weighing the pros and cons in the paragraphs above, it is recommended to use method 2 as base method, since it has the best potential to match the objectives of an effective off-cycle provision method, as laid down in 9.1.

The following modifications are suggested to improve ASEP method 2:

- Remove the 2 m/s^2 boundary in method B. This will improve the position of the ASEP anchor point while it has little effect on the method B result [43] [44].
- Define the limit curve of method 2 in terms of noise emission as function of vehicle speed, rather than as function of engine speed. This will then also enable testing of hybrid and electric vehicles.
- Increase the 4 m/s^2 boundary from the ASEP control range to 5 m/s^2. This will enable testing of high-powered vehicles in 2nd gear as well.
- Expand the ASEP regulation to partial throttle accelerations. This will ensure that all operating conditions of future vehicles will be subject to the ASEP regulation, which is essential for the effectiveness of the combination of type approval and ASEP regulations.
- Change the ASEP coefficients from Delta = 8, Margin = 2, Slopebelow = 3 into Delta = 9, Margin = 3, Slopebelow = 3. This reduces the amount of "uncritical vehicles" which come close to the ASEP limit [45].
- Increase the Delta to 12 for vehicles with PMR > 150 kW/t; this allows high-powered cars an extra margin for noise emission at higher engine speeds if this is desirable for commercial reasons.
- Include the ASEP performance of replacement exhaust systems on the basis of a back to back test compared to the original system.

10 Conclusions and recommendations

10.1 Policy options for change of limit values

At the request of the European Commission, 5 different policy options for the future test method for vehicle noise emission and corresponding limit values were studied with the database of recent vehicle test data as a basis. The conclusions on these 5 options are as follows:

1. Option 1 – No policy change (current test method; no change in limit values)
   This option does not offer any benefit for the reduction of environmental noise. Furthermore the current test method A does not have significant advantages above the new test method B, so this option is not recommended.
2. Option 2 – New test method with current limit values
   This option in fact increases the limit values, because test method B produces lower test results than test method A. This option may lead to an increase of road traffic noise impact of around 1,7 dB(A) and is therefore not advisable.
3. Option 3 – New test method; new limit values equivalent to current limit values.
   This option may be introduced without negative consequences for the current vehicle fleet, but it does not produce any positive effect for the road traffic noise impact. It is therefore not recommended.
4. Option 4 – New test method; new limit values aiming at a reduction of the road traffic noise impact.
   In this option the limit values for light and medium size vehicles will be lowered by 3 dB(A) and for heavy vehicles with 2 dB(A). This will result in a reduction of the noise impact L_{DEN} and L_{night} of 2,5 dB(A) for roads with free flowing traffic. For roads with intermittent traffic, where power train noise is dominant, the noise impact reduction is estimated at 2,8 dB(A). The noise impact reduction will correspond to a decrease of the number of highly noise annoyed people by 20 %.
   As the economic consequences of this policy change for industry are considered manageable, this option can be recommended. This option will yield the highest Benefit-Cost Ratio (20,1). However, the positive environmental and social impact of option 4 will be lower than the impacts of option 5.
5. Option 5 – New test method; new limit values in a two step approach, aiming for a more ambitious reduction of the road traffic noise impact.
   In this option the limit values for light and medium size vehicles will be lowered in two steps of each 2 dB(A) and for heavy vehicles in a first step of 1 and a second step of 2 dB(A). This will result in a reduction of the noise impact L_{DEN} and L_{night} of 3,1 dB(A) for free flowing traffic and upto 4 dB(A) for intermittent traffic. The reduction of the number of highly annoyed people will be 25 %. Also for this option the economic consequences for industry are considered manageable. The Benefit-Cost Ratio of this option (15,7) is somewhat lower than for option 4, but, as this option will give the highest positive environmental and social impacts, it is recommended as the most effective option.

Although the effect of the reduction of limit values proposed under policy option 5 will be significant, the impact assessment shows that it will not lead to a decisive reduction of the number of annoyed and highly annoyed people. If the expected increase in traffic density in the near future is taken into account a part of the predicted positive effects of the limit value reductions will be annulled. Therefore it is recommended to develop a continuous strategy of regular limit value reductions, until a considerably lower noise emission level is attained, that cannot be further reduced without fundamental changes in vehicle technology or in transport modalities.
By announcing such a long term strategy in an early stage the industry will be able to anticipate the future requirements in time and to build its development strategy for new vehicle types on this knowledge.

10.2 Relevance of allowances for vehicles with special characteristics

Based on an analysis of the test results of 1030 vehicles the following conclusions concerning the relevance and justification of the current allowances for vehicles with special characteristics may be drawn:

- The allowance of 1 dB(A) for passenger cars and light vans equipped with a direct injection Diesel engine is no longer justified. All Diesel engines in these types of vehicles are of the direct injection type. The average test results of vehicles with Diesel engines are not higher, but slightly lower than the results for Petrol engines, both in test method A and B. Therefore it is recommended not to implement this allowance in a future system of limit values.
- The allowance of 1 dB(A) for passenger cars with high-powered engines can be sustained. The vehicles that fulfil the criteria for a ‘high power’ qualification show an average noise emission that is 1 dB(A) higher than the average of other passenger cars, both in test method A and B. Due to the fact that the engine power of passenger cars steadily increases it is recommended to revise the criteria for the ‘high power’ qualification in order to ensure that the allowance will only be applicable for vehicles that cannot reasonably be type approved under the normal limit values. The proposed revised criterion is that the vehicle shall have a power to mass ratio greater than 150 kW/tonne.
- The allowance of 1 or 2 dB(A) for vehicle with off-road capabilities finds partial support in the database. Both for passenger cars and for heavy trucks a comparison between normal vehicles and vehicles with off-road capabilities could be made.
- The latter sub categories show a 1 dB(A) higher average noise emission than the normal vehicles for test method B and 1,2 – 1,7 dB(A) for test method A. For policy option 5 with test method B a 1 dB(A) higher limit value for all vehicle categories with off-road capabilities is recommended, under the condition that the vehicles fulfil the off-road criteria according to Article 4 of Annex II of EU Directive 2007/46/EC. For M1 and N1 vehicles this higher limit value should only be applied if the maximum authorised mass of the vehicle exceeds 2 tonnes. A 2 dB(A) higher limit value is proposed for off road trucks of category N3G with an engine power of more than 150 kW.

10.3 Evaluation of test method B

The practicability and manageability of method B was investigated by means of a small enquiry among a number of type approval authorities that had submitted significant numbers of test report files for the database. Based on the response from these type approval authorities the following conclusions can be drawn:

- The complexity of the new method B for light vehicles (M1, N1 and N2 < 3,5t) is approximately three times higher than of the current method A;
- For these vehicles method B requires more attention to avoid errors and to achieve the necessary measurement accuracy than method A;
- Depending on the type of measuring equipment (fully integrated or separate systems) the management of the test process may be rather time consuming;
- Method B is more sensitive to environmental parameters, because the test results for light vehicles are lower than for method A;
- Nevertheless, method B is considered reproducible and manageable;
- For light vehicles there is some ambiguity in the instructions for the choice of gear ratio for automatic transmissions: if an automatic transmission can be locked in a specific gear it is not clear whether the vehicle in question should be tested with locked gears or in the automatic ('Drive") position of the transmission.
- For buses (categories M2 and M3) the complexity of method B is not greater than of method A.
- For heavy goods vehicles the test procedure of method B is more complex than method A due to the requirements for loading of the vehicle;
- The instructions for loading of heavy goods vehicles are not completely clear and unambiguous.

The representativeness of method B for the average noise emission of vehicles in normal traffic is considered better than of method A. This is mainly due to the fact that method B is based on a combination of an acceleration test and a constant speed test. The required acceleration may be considered realistic when compared to accelerations achieved in normal traffic. As the final result is obtained by weighted averaging of both partial test results, the balance between the contributions from powertrain noise and tyre rolling noise in this result is approximately 50-50%.
The consequence is that the test result is less representative for conditions with higher noise emissions, e.g. during fast acceleration. Moreover, as the acceleration test is mostly carried out at rather low engine speeds, the method is not very suitable to reveal noise emission effects that occur mainly at high engine speeds, such as exhaust system modifications.

A concern from the Japanese Automobile Standards Internationalization Center that test method B would not be suitable or representative for the special sub-categories of very small M1 and N1 vehicles that are indicated in Japan as Kei-cars, could not be confirmed after a comparative analysis of the Kei-car noise emission test results and the general test results of M1 and N1 vehicles.

In the available data files of the test results there is no evidence of optimisation of the vehicles to comply with test method B. Therefore the distributions of method B test results show a more natural tapering off to higher noise emission values than the results of method A, which cut off rather sharply at the current limit values. It may be expected that after a longer period of adaptation to the new method, similar effects will develop. For passenger cars this may result in a reduction of the noise emission test results with 1 to 7 dB(A) and may concern 10 – 15 % of the vehicles.

In test method B stricter instructions are give for the mounting of tyres during the test than in test method A. Especially for trucks this should result in the application of representative traction tyres on drive axles during the test instead of steering tyres, as is currently rather common. From the data files it appears that traction tyres were generally used on the drive axles during test B. A number of trucks was tested with several types of tyres, so an analysis could be made of the difference in noise emission between traction tyres and steering tyres mounted on the drive axles. This difference appeared to be 0,6 to 1,0 dB(A), depending on the type of traction tyre. The conclusion is that the choice of tyres on the drive axle of trucks and the effect of high torque exerted on traction tyres does not have a major influence on the test results of heavy trucks.

10.4 Recommended modifications of test method B

In view of the observations and conclusions discussed above the following recommendations for modifications of test method B can be made:

- To delete the requirement that the acceleration during the Wide Open Throttle test of light vehicles shall not exceed 2 m/s^2;
- To revise the instructions for the choice of gear ratios for automatic transmissions that can be locked in a specific gear ratio;
- To revise the instructions for the loading of heavy vehicles and the distribution of the load over the axles of the vehicle.

10.5 Off-cycle emission provisions

Due to the emphasis of test method B on representativeness for noise emission in normal traffic it is less suitable to reveal and control the noise emission under worst case conditions, e.g. during fast acceleration and during operation at high engine speeds. This observation is primarily relevant for passenger cars, in particular with a high rated engine power, because these vehicles have a large range of operating conditions that may deviate significantly from the conditions during the test. In order to control the maximum noise emissions of a vehicle in a more effective way than test method B is capable of, off-cycle emission provisions are considered to be essential. The methodology for Additional Sound Emission Provisions (ASEP), that is being developed in UNECE GRB Informal Group ASEP, was studied, as well as some alternative methods to limit off-cycle emissions. This resulted in the following conclusions:

- For the near future, the approach of the ASEP methodology will be the most effective way to limit and control off-cycle emissions of vehicles of category M1 and N1;
- For other vehicle categories, off-cycle emission provisions do not seem necessary, because the test result of method B may be considered as an adequate predictor of the noise emission under deviating operating conditions;
- Both methods developed for the ASEP methodology, method 1 developed in the GRB Informal Group ASEP and method 2 submitted by the Netherlands, suffer from serious shortcomings, that prevent their immediate implementation;
- Method 2, submitted by the Netherlands, is recommended for further development, because is has the best potential to match the objectives for an off-cycle provision method;

The recommendations for modification of ASEP method 2 are:

- To remove the 2 m/s^2 boundary in method B (see also 10.4);

- To define the limit curve of method 2 in terms of noise emission as function of vehicle speed, rather than as function of engine speed;
- To increase the 4 m/s^2 boundary from the ASEP control range to 5 m/s^2;
- To expand the ASEP regulation to partial throttle accelerations;
- To change the ASEP coefficients from Delta = 8, Margin = 2, Slopebelow = 3 into Delta = 9, Margin = 3, Slopebelow = 3;
- To increase the Delta to 12 for vehicles with PMR > 150 kW/t;
- To include the ASEP performance of replacement exhaust systems on the basis of a back-to-back test compared to the original system..

Further recommendations are:

- To introduce a general requirement that the manufacturer shall guarantee that the vehicle shall not under any operating condition produce a noise emission that cannot be predicted from the results of the type approval test according to method B and generally accepted physical laws relating noise emission to engine load and engine speed;
- To designate the ASEP methodology as a method of testing whether the guarantee of the manufacturer is fulfilled, but not as a separate requirement that would supplement the basic limit value requirements based on test method B;
- To consider for the more distant future the development and introduction of an indoor noise emission test on a test bench based on a comprehensive test cycle that should incorporate many different operating conditions, similar to the test cycles for CO_2 and exhaust emissions.

10.6 Impact assessment

The environmental impact was determined in terms of effect of the policy options on L_{DEN}, L_{night} and single event levels taking different road types, traffic types and population exposure for each road type into account. Due to high numbers of cars compared to other vehicles on most roads they generally tend be the dominant factor for L_{DEN} and L_{night} levels.

Current levels of L_{DEN} for exposed people along different average road types included in the analysis vary between 52-74 dB and for L_{night} between 43 and 65 dB. Although lower levels occur along residential and main roads than arterial roads and motorways, they are quite significant in terms of impact due to the number of exposed people and the large length of such roads in the EU.

The environmental benefit in terms of noise levels is clearly greatest for options 4 and 5, with reductions in L_{DEN} and L_{night} on average 2,5 dB for option 4 and 3,1 dB for option 5. Higher reductions are reached for roads with intermittent traffic where powertrain noise is dominant, 2,8 dB for option 4 and 4 dB for option 5.
Option 2 results in a net increase in in L_{DEN} and L_{night} levels of around 1,7 dB, whilst options 1 and 3 have no effect, reflecting the baseline situation.

Part of the expected traffic noise reduction will be from reduction of tyre noise due to the tyre directive, especially on roads with free flowing traffic and speeds above 50 km/h. But powertrain noise also has to be reduced somewhat to fulfil new limits. This is especially the case for vans, lorries, HGVs and buses.

For roads with intermittent traffic, which affect a substantial part of the population, a major part of the noise reduction has to be achieved on powertrain noise for all vehicle types.

Annual growth in road traffic is projected at approximately 1,6 % for cars, 0,6 % for buses and coaches and 1,2 % for road freight (vans, lorries and HGVs). In 10 years, L_{DEN} and L_{night} levels increase by around 0,6 dB for all road types. This increase in traffic volume can diminish the gained noise reduction and the associated benefits. Over a 20 year period, without any countermeasures, the reductions in L_{DEN} and L_{night} could be diminished by 1,2 dB, resulting in only 1,3 dB for option 4 and 2,7 dB for option 5.

Single event levels remain unchanged for options 1 and 3, and may increase by around 1-2,8 dB for option 2. For option 4 they would reduce by 3,2 dB for cars and vans, 3 dB for buses and 2 dB for lorries and HGVs. For options 5, they would reduce 4,6 dB for cars, 4,4 dB for vans, 4 dB for buses, and 3 dB for lorries and HGVs.

The social impact in terms of numbers of highly annoyed people and highly sleep disturbed people is significant. For the current situation (option 1) an estimated 55 million people are highly annoyed by road traffic and 27 million are highly sleep disturbed. These numbers are reduced to 44/22 million for option 4 and 41/22 million for option 5. Option 2 leads to an increase of 9/3 million. The reductions for options 4 and 5 will also lead to an increased quality of life for millions of people, with reduced stress levels and improvement in work, home and recreational environments. However, due to projected traffic growth over a period of 10 years, numbers of highly annoyed and highly sleep disturbed people grow by 3 million and 1 million respectively.

The impact on health can be quantified by Disability Adjusted Life Years (DALYs), which takes into account lost productive time and actual lost life years due to various types of disease. Annual numbers of DALYs due to current noise levels are estimated at upto 6,5 million related to annoyance and 3 million related to sleep disturbance. It is estimated that options 4 and 5 reduce the number of DALYs by 0,1-1,4 million for option 4 and by 0,1-1,6 million for option 5.

The economic impact consists of benefits to society due to reduced traffic noise and costs for the vehicle industry due to reducing noise levels of vehicles, in particular the powertrain noise, as tyre noise will be reduced due to the tyre directive.

The impact on the vehicle industry consists primarily of additional development and production costs due to extra reduction of powertrain noise on vehicles. These costs are lower per vehicle unit for cars and vans than for heavy vehicles such as lorries, HGVs and buses.

The accumulated costs amount to 5 billion Euros for option 4 and 7,7 billion Euros for option 5. These costs are incurred over a development and production cycle of 3+7 years and consist mainly of additional production costs which are no longer incurred after 10 years.

The accumulated benefits for society consist of valuation of noise reduction, healthcare savings and savings on noise abatement on road infrastructure and dwellings. By far the largest benefits are due to hedonic pricing related to perceived value of noise reduction, followed to a lesser extent by healthcare savings and relatively smaller savings on noise abatement costs.

Together, these benefits are in the order of 101 billion Euros for option 4 and 120 billion Euros for option 5 over the period 2010-2030. The benefits outweigh the costs for industry by a factor 20,1 for option 4 and a factor 15,7 for option 5. The benefits increase gradually and are sustained over 20 years, whereas the costs for industry occur from 2-3 years before and upto 7 years after the limits are changed. The environmental and social benefits may be reduced by half if traffic growth continues at current rates.

10.7 Recommended Amendment of Council Directive 70/157/EEC

Based on the conclusions with respect to the analysis of the 5 policy options and to the relevance of the current system of allowances it is recommended to revise Article 2 of Annex I and Annex III of Council Directive 70/157/EEC as follows:

2. SOUND LEVEL OF MOVING VEHICLES

2.1 Limiting values

The sound level measured in accordance with the provisions of Annex II shall not exceed the following limits:

	Vehicle category	Description of vehicle category	Limit values expressed in dB(A) [decibels(A)]					
			Limit values for Type approval of new vehicle types		Limit values for Type approval of new vehicle types		Limit values for First Registration of new vehicles	
			Stage 1 valid from 1 January 2013		Stage 2 valid from 1 January 2015		Stage 3 valid from 1 January 2017	
			General	Off-road *	General	Off-road *	General	Off-road *
2.1.1	**M**	**Vehicles used for the carriage of passengers**						
2.1.1.1.1	M1	no of seats ≤ 9	70	71**	68	69**	68	69**
2.1.1.1.2	M1	no of seats ≤ 9; power to mass ratio > 150 kW/tonne	71	71	69	69	69	69
2.1.1.2.1	M2	no of seats > 9; mass ≤ 2 tonnes	72	72	70	70	70	70
2.1.1.2.2	M2	no of seats > 9; 2 tonnes < mass ≤ 3,5 tonnes	72	73	70	71	70	71
2.1.1.2.3	M2	no of seats > 9; 3,5 tonnes < mass ≤ 5 tonnes; rated engine power < 150 kW	73	74	71	72	71	72
2.1.1.2.4	M2	no of seats > 9; 3,5 tonnes < mass ≤ 5 tonnes; rated engine power ≥ 150 kW	74	75	72	73	72	73
2.1.1.3.1	M3	no of seats > 9; mass > 5 tonnes; rated engine power < 150 kW	75	76	73	74	73	74
2.1.1.3.2	M3	no of seats > 9; mass > 5 tonnes; rated engine power ≥ 150 kW	77	78	75	76	75	76
2.1.2	**N**	**Vehicles used for the carriage of goods**						
2.1.2.1.1	N1	mass ≤ 2 tonnes	71	71	69	69	69	69
2.1.2.1.2	N1	2 tonnes < mass ≤ 3,5 tonnes	72	73	71	72	71	72
2.1.2.2.1	N2	3,5 tonnes < mass ≤ 12 tonnes; rated engine power < 75 kW	74	75	72	73	72	73
2.1.2.2.2	N2	3,5 tonnes < mass ≤ 12 tonnes; 75 ≤ rated engine power < 150 kW	75	76	73	74	73	74
2.1.2.2.3	N2	3,5 tonnes < mass ≤ 12 tonnes; rated engine power ≥ 150 kW	77	78	75	76	75	76
2.1.2.3.1	N3	mass > 12 tonnes; 75 ≤ rated engine power < 150 kW	77	78	75	76	75	76
2.1.2.3.2	N3	mass > 12 tonnes; rated engine power ≥ 150 kW	80	82	78	80	78	80

* Increased limit values are only valid if the vehicle complies with the relevant definition for off-road vehicles according to article A.4 of Annex II of EU Directive 2006/46/EC

** For M1 vehicles the increased limit values for off-road vehicles are only valid if the maximum authorised mass > 2 tonnes

2.2 Interpretation of results

2.2.1. The measurements are considered valid if the difference between two consecutive measurements on the same side of the vehicle does not exceed 2 dB(A).

2.2.3. The highest sound level measured shall constitute the test result. Should the result exceed the maximum permissible sound level for the category of vehicle tested by 1 dB(A), two further measurements shall be made at the corresponding microphone position. Three of the four measurements thus obtained at that microphone position must fall within the prescribed limits.

Annex III of Council Directive 70/157/EEC shall specify the description of method B with the revisions recommended in 10.4.

11 References

[1] EU Directive 70/157/EEC on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles, Council Directive of 6 February 1070, Brussels, Official Journal L 042, 23/02/1970 P. 0016 – 0020.

[2] Regulation No 51 – Addendum 50 – Revision 1 – Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions, Regulation UN/ECE, Geneva, Switzerland, 30 May 2007.

[3] EU Directive 2007/34/EC amending, for the purposes of its adaptation to technical progress, Council Directive 70/157/EEC concerning the permissible sound level and the exhaust system of motor vehicles, Commission Directive of 14 June 2007, Brussels, Official Journal L 155, 15/06/2007, P. 49 – 67.

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12 Signature

Delft, 13 August 2010

TNO Science and Industry

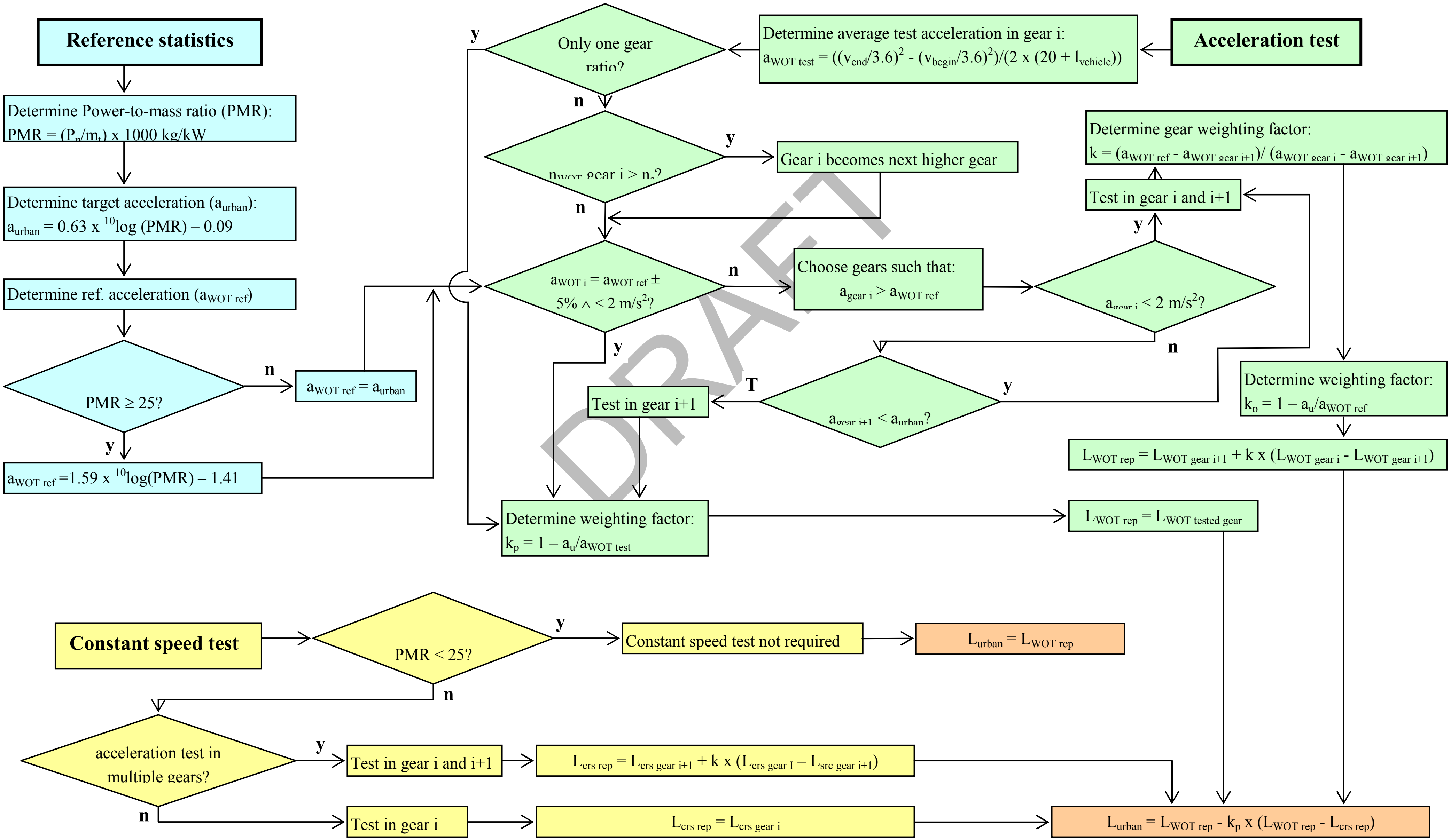
P. Hendriksen, BSc.

Head of department

F. de Roo, MSc.
M.G. Dittrich, MSc.
P.J.G. van Beek, MSc.
C. Bosschaart, MSc.
G.B. Derksen, MSc.
M. de Kievit, MSc.

Authors

A Flow chart of test procedure according to Method B for light vehicles (M1, N1 and M2 ≤ 3,5 t)



B Required distance for acceleration for various vehicle and traffic types

B.1 Introduction

Road traffic behaves differently on different road types. For example the quantity and intensity of acceleration of road traffic varies per vehicle type (e.g. passenger cars or trucks) and per traffic type (e.g. urban or motorway). In order to estimate the fraction of acceleration of light vehicles (passenger cars and light commercial vehicles) and heavy vehicles (heavy trucks), both their driving characteristics must be analyzed.

B.2 Method

In order to get the fraction accelerated distance of the total travelled distance, different driving cycles were used for different vehicle types. The analyzed driving cycles are known as representative for real life situations. For light vehicles the complete Artemis Cycle[1] (Figure 29) was analyzed, for heavy vehicles a TNO developed cycle (Figure 30) was selected. For these cycles the distance covered with an acceleration higher than a certain threshold were counted up. This threshold is applied to filter out small accelerations and decelerations during constant driving. Finally this counted up accelerated distance was divided by the total covered distance to get the fraction of acceleration.

B.3 Conclusions

In Table 39 and Table 40 the fraction acceleration of the total covered distance is shown for respectively light and heavy vehicles for various traffic types (i.e. urban, rural and motorway) and various thresholds (i.e. 0.25 m/s^2, 0.5 m/s^2, 1 m/s^2 and 1.5 m/s^2).

Table 39 - The fraction acceleration of the total covered distance for light vehicles on various traffic types

Light vehicles

% of distance	a = 0.25 m/s2	a = 0.5 m/s2	a = 1 m/s2	a = 1.5 m/s2
Urban	38.29%	27.99%	10.94%	4.11%
Rural	22.88%	13.28%	2.39%	0.43%
Motorway	13.94%	3.47%	0.63%	0.00%

Table 40 - The fraction acceleration of the total covered distance for heavy vehicles on various traffic types

Heavy vehicles

% of distance	a = 0.25 m/s2	a = 0.5 m/s2	a = 1 m/s2	a = 1.5 m/s2
Urban	24.28%	8.65%	0.68%	0.00%
Rural	17.46%	4.64%	0.00%	0.00%
Motorway	0.00%	0.00%	0.00%	0.00%

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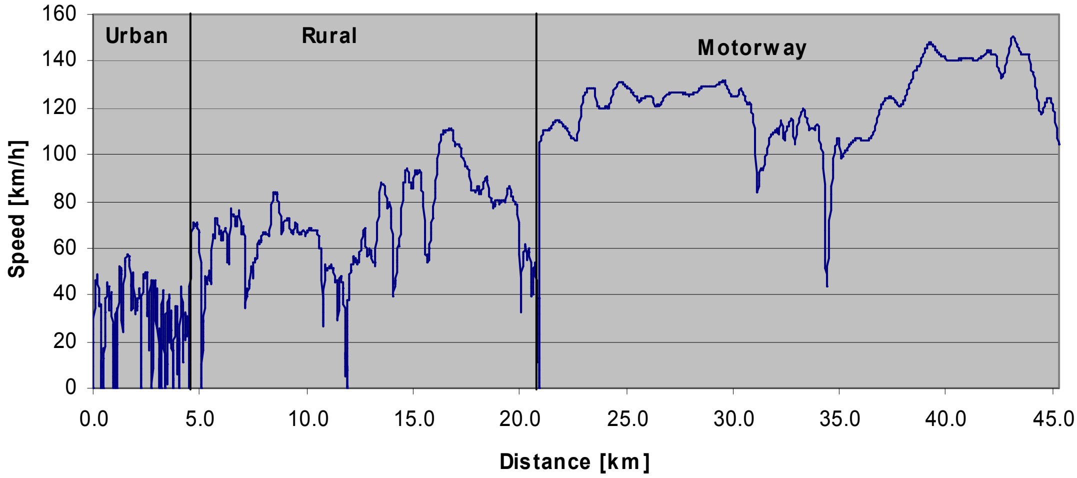

Figure 29 - Artemis cycle

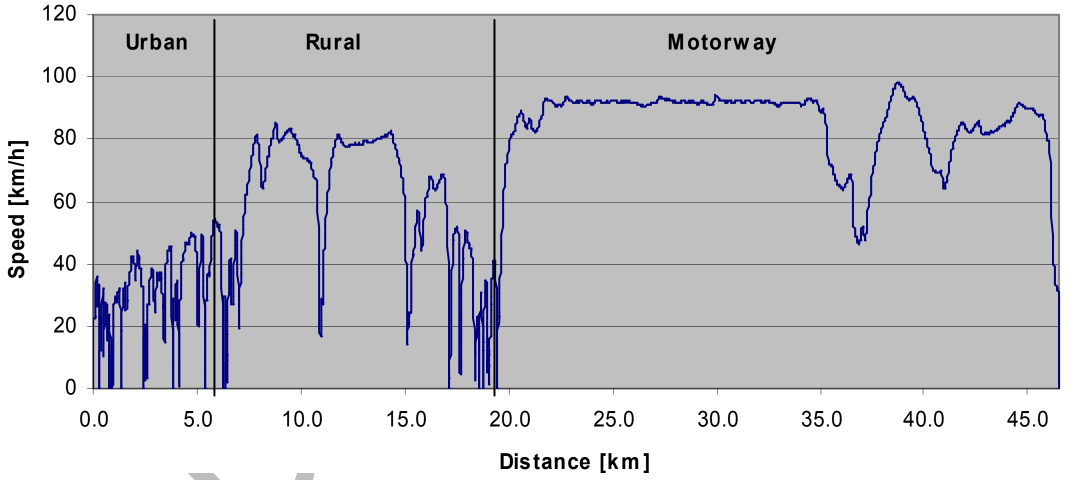

Figure 30 - TNO developed HD cycle

C Traffic intensities, derived vehicle emission levels and growth effects

C.1 Traffic intensities

The traffic intensities (flow rates) considered representative for the different European road types are set out in Table 41. These have been compared with intensities found from noise mapping in Amsterdam and Rotterdam, but also related to L_{DEN} noise levels on noise maps in European cities. Intensities on individual roads may differ significantly from these average values.

Table 41 - Average traffic intensities used as input to the environmental noise calculation.

	Residential	Main	Arterial	Urban MW	Rural MW	Rural
Typ.speed	<50	<50	50-70	70-120	80-130	50-100
	Typical traffic intensities N/hour					
DAY 12h	Intmt.+free	Intmt.+free	Free	Free	Free	Free
Pass. Cars	20	500	1000	2000	2000	100
Vans	4	50	100	200	200	10
Lorries	0,2	25	50	100	100	10
Buses	0,1	4	10	10	10	2
HDVs	0,1	15	50	120	130	5
EVE 4h						
Pass. Cars	15	400	1000	1500	1500	50
Vans	2	20	100	150	150	5
Lorries	0,01	4	20	50	50	2
Buses	1	2	10	6	6	2
HDVs	0,01	5	20	90	90	2
NIGHT 8h						
Pass. Cars	2	50	200	500	500	16
Vans	1	5	20	50	50	2
Lorries	0,01	2	17	35	35	1
Buses	0,5	1	5	4	4	1
HDVs	0,01	2	8	50	50	1

C.2 Vehicle Sound emission levels

The noise emission levels used as inputs for the calculation are L_{pAmax} levels derived from the following Table 42. The data has been derived from the UBA vehicle noise database [23] and adjusted according to the regression curves of the EU type test database.

Table 42 - Vehicle noise emission levels L_{pAmax} at 7,5m distance derived for different policy options. A and B refer to the measurement method. The lower table shows noise levels characteristic for average traffic. The upper table gives levels based on averages of type test values from the EU Circa database. Values from the lower table are used as inputs to the L_{DEN} calculations.

Noise emission levels based on Circa data-base data														
		UBA - Steven			Option 1		Option 2		Option 3		Option 4		Option 5	
		Speed	Lmax		A = Ref	B	A	B	A	B = Ref	A	B	A	B
		Fill in												
Pass. Cars	Accelerating	50	73,88		72,15	71,02	74,86	72,93	72,03	70,94	67,79	67,78	66,37	66,35
	Free flow	50	72,49			68,30		70,21		68,22		65,62		65,62
Buses	Accelerating	30	77,66		76,88	75,65	80,49	77,64	77,30	75,78	73,38	73,43	71,66	72,43
	Free flow	30	74,96			0,00		0,00		0,00		0,00		0,00
Vans	Accelerating	50	76,44		74,10	73,02	79,17	75,52	73,51	72,61	67,76	69,46	65,84	68,25
	Free flow	50	74,18			70,82		73,32		70,42		68,06		68,06
Lorries	Accelerating	40	80,70		76,20	73,91	80,10	76,48	76,95	74,40	73,92	72,40	72,40	71,40
	Free flow	40	77,13			0,00		0,00		0,00		0,00		0,00
HDVs	Accelerating	40	84,33		80,15	80,09	79,84	79,78	80,51	80,46	78,51	78,46	77,51	77,46
	Free flow	40	80,61			0,00		0,00		0,00		0,00		0,00

Noise emission levels based on UBA study														
		UBA - Steven			Option 1		Option 2		Option 3		Option 4		Option 5	
		Speed	Lmax		A = Ref	B	A	B	A	B = Ref	A	B	A	B
Pass. Cars	Accelerating	50	73,88		**73,88**	73,96	76,59	**75,88**	73,77	**73,88**	69,52	**70,73**	68,11	**69,30**
	Free flow	50	72,49		**72,49**	72,57	75,19	**74,48**	72,37	**72,49**	68,13	**69,89**	66,71	**69,89**
Buses	Accelerating	30	77,66		**77,66**	77,54	81,27	**79,53**	78,08	**77,66**	74,16	**75,31**	72,44	**74,31**
	Free flow	30	74,96		**74,96**	74,84	78,57	**76,83**	75,38	**74,96**	71,46	**72,61**	69,74	**71,61**
Vans	Accelerating	50	76,44		**76,44**	76,85	81,51	**79,35**	75,85	**76,44**	70,10	**73,29**	68,18	**72,08**
	Free flow	50	74,18		**74,18**	74,59	79,24	**77,09**	73,59	**74,18**	67,84	**71,82**	65,92	**71,82**
Lorries	Accelerating	40	80,70		**80,70**	80,21	84,60	**82,78**	81,45	**80,70**	78,42	**78,70**	76,90	**77,70**
	Free flow	40	77,13		**77,13**	76,63	81,03	**79,21**	77,87	**77,13**	74,84	**75,13**	73,33	**74,13**
HDVs	Accelerating	40	84,33		**84,33**	83,97	84,02	**83,66**	84,70	**84,33**	82,70	**82,33**	81,70	**81,33**
	Free flow	40	80,61		**80,61**	80,24	80,29	**79,93**	80,97	**80,61**	78,97	**78,61**	77,97	**77,61**

C.3 Derivation of future traffic noise emission levels

In order to explain the computation procedure for the future noise emission levels in real traffic the complete derivation of one of the levels, the maximum A-weighted pass-by sound pressure level of accelerating vehicles according to option 4 ($L_{traf,opt4,acc}$) is given as an example of this computation procedure. For other traffic conditions and other policy options similar derivations were used, that may deviate slightly from the given example.

Example $L_{traf,opt4,acc}$

The quantity $L_{traf,opt4,acc}$, the maximum A-weighted pass-by sound pressure level per vehicle in real traffic for accelerating vehicles of a specific vehicle group for future policy option 4 is given by:

$$L_{traf,opt4,acc} = L_{traf,UBA,acc} + (\overline{L}_{WOT,opt4} - \overline{L}_{WOT,opt3})$$

Where:

$L_{traf,UBA,acc}$ is the average noise emission value calculated with the regression equation from the UBA report for accelerating vehicles of the relevant vehicle group

The reduction of the noise emission during acceleration in real traffic for future policy option 4 is calculated from the difference between the predicted average WOT (Wide Open Throttle) test result for policy option 4, $L_{WOT,opt4}$, and the average WOT test result for policy Option 3, $L_{WOT,opt3}$, which is equivalent to the current situation. The predicted value $L_{WOT,opt4}$ can be derived as:

$$\overline{L}_{WOT,opt4} = (\overline{L}_{Urban,opt4} - \overline{k}_p . \overline{L}_{CRS.opt4})/(1 - k_p)$$

Where:

$$\overline{L}_{Urban,opt4} = \overline{L}_{Urban,opt3} + (\overline{L}_{limit,opt4} - \overline{L}_{limit,opt3})$$

$\overline{k}_p = \dfrac{\overline{L}_{Urban,op3} - \overline{L}_{WOT,opt3}}{\overline{L}_{WOT,opt3} - \overline{L}_{CRS,opt3}}$ is the average partial power factor that can be derived from the database with vehicle test results according to test B:

$$\overline{L}_{WOT,opt3} = \overline{L}_{WOTrep,testB}$$

$$\overline{L}_{Urban,opt3} = \overline{L}_{Urban,testB}$$

$$\overline{L}_{CRS,opt3} = \overline{L}_{CRSrep,testB}$$

Both limit values for options 3 and 4 ($L_{limit,opt3}$; $L_{limit,opt4}$) are taken from the table with proposed limit values per policy option. The mean limit value for a vehicle group is obtained by weighted averaging of the limit values per vehicle (sub)category, where the weighting factors are the numbers of each vehicle (sub) category in the database. Furthermore the predicted value of the constant speed test result according to method B under policy option 4 is obtained with the following equation:

$$\overline{L}_{CRS,opt4} = 10.lg(10^{(\overline{L}_{Roll,opt4})/10} + 10^{(\overline{L}_{Engine,CRS,opt3})/10})$$

In this equation the rolling noise contribution to the test result ($L_{Roll,opt4}$) is assumed to be equal during the acceleration test and the constant speed test. The average value of this quantity in option 4 the value is based on the average value derived from the current test results ($L_{Roll,opt3}$) reduced with average reduction of tyre-road noise due to the reduction of the limit values for rolling noise according to EU Regulation 661/2009:

$$\overline{L}_{Roll,opt4} = \overline{L}_{Roll,opt3} + \overline{\Delta L}_{limit,tyre}$$

For the C1 class of tyres the average reduction is estimated at -3,8 dB(A), and for C2 and C3 class of tyres at -3,0 dB(A) (See also Appendix D).

The power train noise contribution to the constant speed test result of method B ($L_{PowTr,CRS,opt3}$) is estimated at:

$$\overline{L}_{Engine,CRS,opt3} = \overline{L}_{CRS,opt3} - 4dB$$

C.4 Effect of fleet and mileage growth on average car fleet emission

The reduction in traffic noise levels will be diminished over time if the fleet size and annual mileage grows. These affects are illustrated for options 4 and 5 in the figures below.

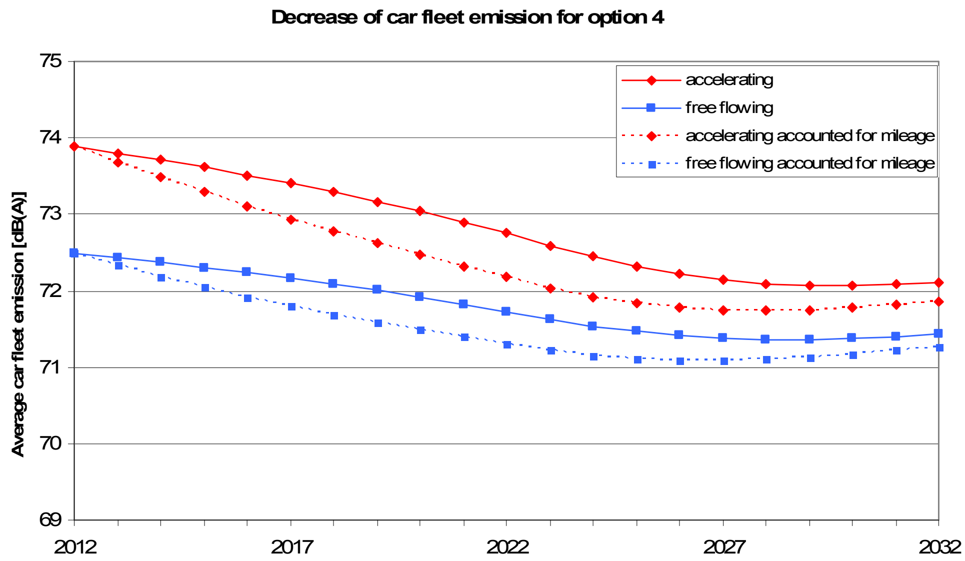

Figure 31 – Decrease of the average noise emission of the whole car fleet taking fleet size growth and mileage growth into account, for option 4.

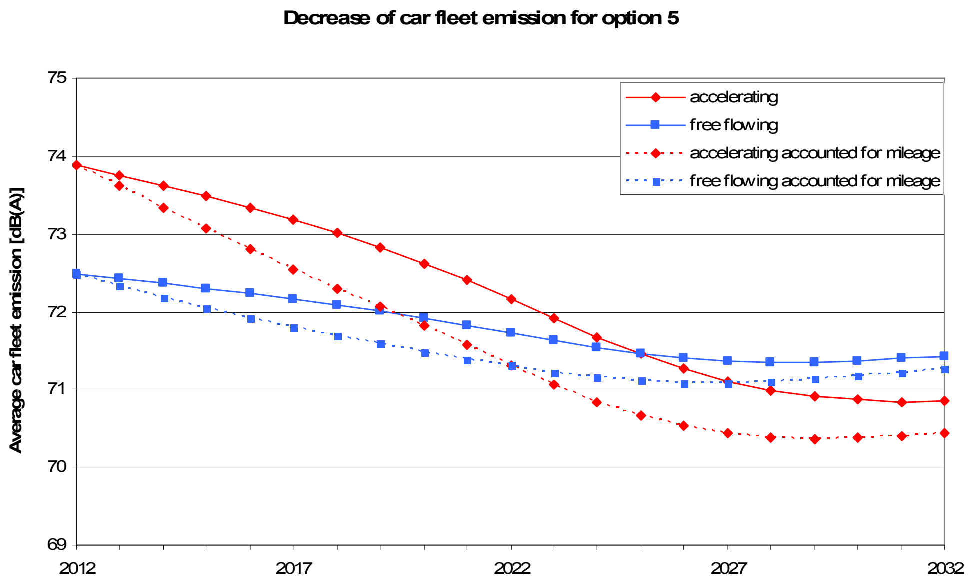

Figure 32 - Decrease of the average noise emission of the whole car fleet taking fleet size growth and mileage growth into account, for option 5.

D Non-compliance with possible limit values

This Appendix presents the numbers and percentages of vehicles within each vehicle category that would not comply with a specific limit value. The test results are rounded to the nearest integer value before verifying whether a result is smaller than or equal to a possible limit value (in which case it satisfies this value) or larger than the value (in which it does not satisfy it).
The chosen way of presenting the non-compliant test results may be statistically interpreted as the probability to exceed a possible limit value; these probabilities are equal to 100% minus the cumulative distribution values.

The data are presented as numbers in Table 43 and as percentages in Table 44. The percentage distributions for method A and B are presented in graphical form in Figure 33 and Figure 34.

N.B. When using the information from the non-compliance tables and graphs one should be aware that these data apply to the vehicles that were tested during the last 3 years. As the proposed limit values will only be applicable for vehicle types that will be introduced on the market after the revised limit values are put into force, the presented data do not necessarily apply to these future vehicle types.

Table 43 - Numbers of vehicles per category that would **not** satisfy a certain limit value for test method A or B – based on the test results of the vehicles in the Circa database

Possible limit value [dB(A)]	Cut-off value [dB(A)]	Number of non-compliant vehicles																	
		method A									method B								
		M1	M1G	M2	M3	N1	N1G	N2	N3	N3G	M1	M1G	M2	M3	N1	N1G	N2	N3	N3G
62	62,5	647	24	28	75	52	3	55	100	39	647	24	28	75	52	3	55	100	39
63	63,5	647	24	28	75	52	3	55	100	39	647	24	28	75	52	3	55	100	39
64	64,5	647	24	28	75	52	3	55	100	39	645	24	28	75	52	3	55	100	39
65	65,5	647	24	28	75	52	3	55	100	39	641	24	28	75	52	3	55	100	39
66	66,5	647	24	28	75	52	3	55	100	39	630	24	28	75	52	3	55	100	39
67	67,5	643	24	28	75	52	3	55	100	39	599	23	28	75	52	3	55	100	39
68	68,5	619	24	28	75	52	3	55	100	39	507	22	28	75	48	3	55	100	39
69	69,5	583	24	28	75	52	3	55	100	39	380	18	27	75	46	3	55	100	39
70	70,5	533	23	27	75	50	3	55	100	39	238	13	26	75	46	3	54	100	39
71	71,5	428	19	26	75	47	3	55	100	39	141	6	21	75	36	3	51	100	39
72	72,5	304	15	21	75	37	2	51	100	39	67	6	16	73	17	3	43	100	39
73	73,5	150	11	16	74	28	2	47	100	39	34	4	14	70	10	2	38	100	39
74	74,5	42	8	15	73	21	2	45	99	39	11	2	10	66	5	1	30	100	39
75	75,5	0	3	9	66	9	2	32	99	39	5	0	3	58	2	1	26	100	39
76	76,5	0	0	7	58	6	1	30	99	39	4	0	2	47	0	0	18	100	39
77	77,5	0	0	2	42	1	1	22	98	39	3	0	2	39	0	0	13	98	39
78	78,5	0	0	0	30	0	0	5	93	39	2	0	0	17	0	0	5	95	39
79	79,5	0	0	0	19	0	0	1	74	39	2	0	0	11	0	0	3	88	39
80	80,5	0	0	0	2	0	0	0	11	31	1	0	0	7	0	0	0	66	34
81	81,5	0	0	0	1	0	0	0	3	26	0	0	0	1	0	0	0	33	28
82	82,5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	10	14
83	83,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2
84	84,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
85	85,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 44 - Percentage of vehicles per category that would **not** satisfy a certain limit value for test method A or B – based on the test results of the vehicles in the Circa database.

Possible limit value [dB(A)]	Cut-off value [dB(A)]	Percentage non-compliant vehicles																	
		Test method A									Test method B								
		M1	M1G	M2	M3	N1	N1G	N2	N3	N3G	M1	M1G	M2	M3	N1	N1G	N2	N3	N3G
62	62,5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
63	63,5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
64	64,5	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
65	65,5	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100
66	66,5	100	100	100	100	100	100	100	100	100	97	100	100	100	100	100	100	100	100
67	67,5	99	100	100	100	100	100	100	100	100	93	96	100	100	100	100	100	100	100
68	68,5	96	100	100	100	100	100	100	100	100	78	92	100	100	92	100	100	100	100
69	69,5	90	100	100	100	100	100	100	100	100	59	75	96	100	88	100	100	100	100
70	70,5	82	96	96	100	96	100	100	100	100	37	54	93	100	88	100	98	100	100
71	71,5	66	79	93	100	90	100	100	100	100	22	25	75	100	69	100	93	100	100
72	72,5	47	63	75	100	71	67	93	100	100	10	25	57	97	33	100	78	100	100
73	73,5	23	46	57	99	54	67	85	100	100	5	17	50	93	19	67	69	100	100
74	74,5	6	33	54	97	40	67	82	99	100	2	8	36	88	10	33	55	100	100
75	75,5	0	13	32	88	17	67	58	99	100	1	0	11	77	4	33	47	100	100
76	76,5	0	0	25	77	12	33	55	99	100	1	0	7	63	0	0	33	100	100
77	77,5	0	0	7	56	2	33	40	98	100	0	0	7	52	0	0	24	98	100
78	78,5	0	0	0	40	0	0	9	93	100	0	0	0	23	0	0	9	95	100
79	79,5	0	0	0	25	0	0	2	74	100	0	0	0	15	0	0	5	88	100
80	80,5	0	0	0	3	0	0	0	11	79	0	0	0	9	0	0	0	66	87
81	81,5	0	0	0	1	0	0	0	3	67	0	0	0	1	0	0	0	33	72
82	82,5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	10	36
83	83,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5
84	84,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
85	85,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

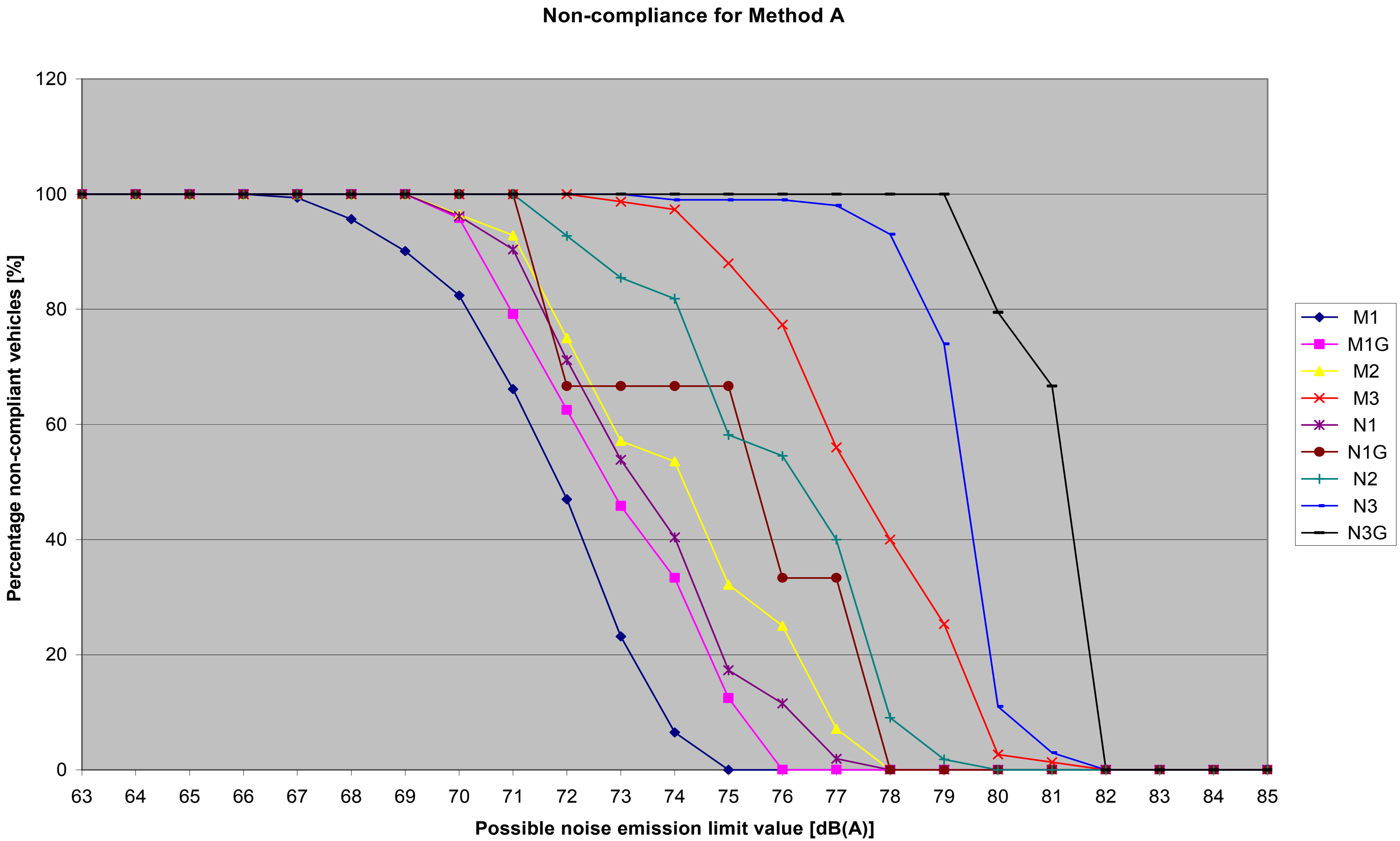

Figure 33 - Graphic presentation of the percentage of vehicles that would **not** satisfy a certain limit value, based on the results of test method A.

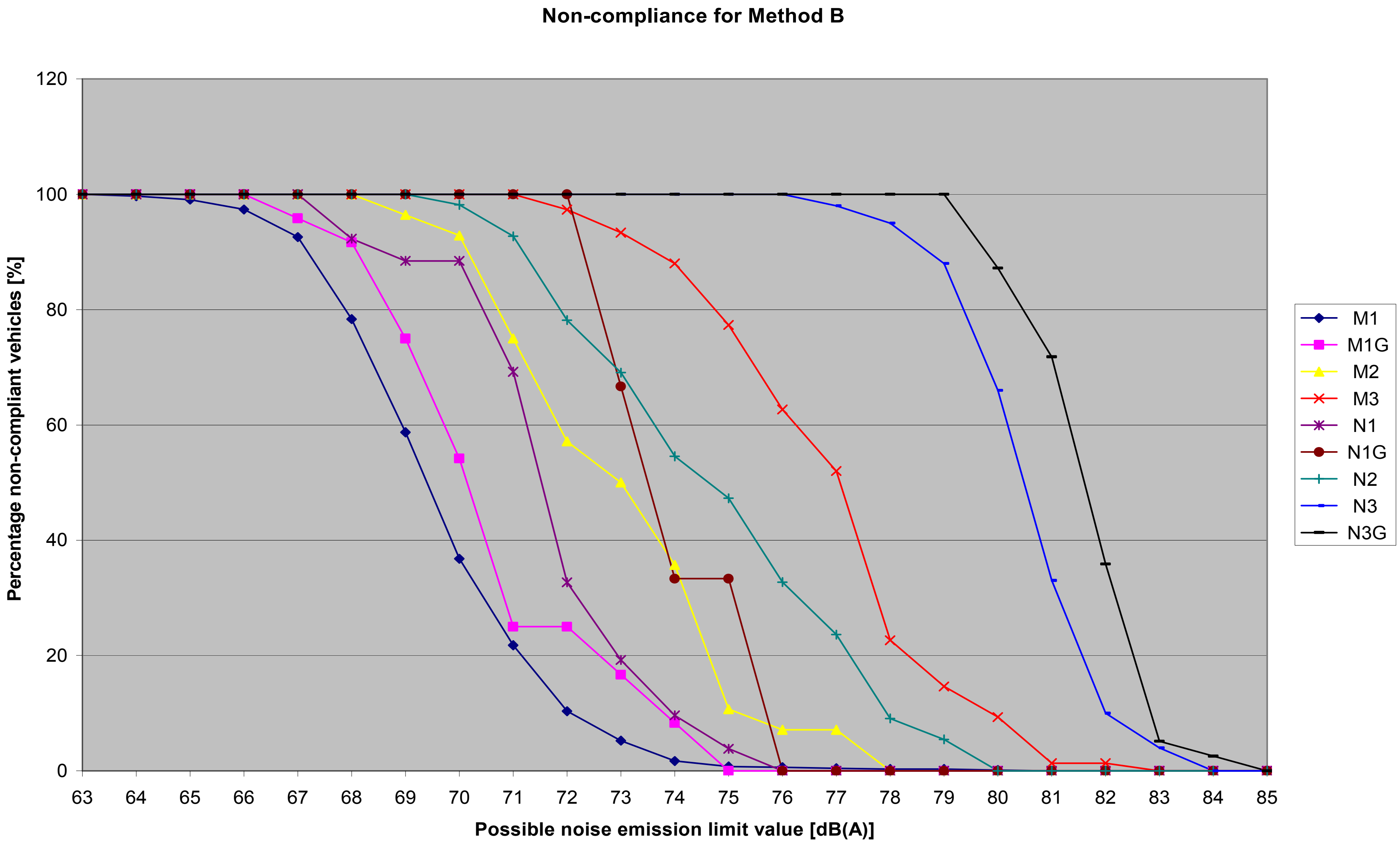

Figure 34 - Graphic presentation of the percentage of vehicles that would **not** satisfy a certain limit value, based on the results of test method B.

E Calculation of tyre-road noise contributions to vehicle noise test results

E.1 Tyre-road noise and power train noise contributions to test results

Tyre road noise (= rolling noise) contributions can be computed for those vehicles for which test method B prescribes a constant speed test in addition to the WOT (Wide Open Throttle) test. This is the case for vehicle categories M1, M1G, M2 (< 3500kg), N1 and N1G.

For these vehicles the following test results are reported for method B:
$L_{wot\ rep}$ is the reported test result of the WOT test
$L_{crs\ rep}$ is the reported test result of the constant speed (cruise-by) test

$L_{urban} = L_{wot\ rep} - k_p.(L_{wot\ rep} - L_{crs\ rep})$ is the final result of test method B

In which:
$k_p = 1 - (a_{urban} / a_{wot\ test})$ is the partial power factor for urban driving.

Based on a few assumptions it is possible to estimate the rolling noise contribution and the power train noise contribution during the constant speed test and the WOT test.

The first assumption is that the measured total noise emission $L_{crs\ rep}$ during the constant speed test is dominated by rolling noise. As a rather conservative estimate it is assumed that the power train noise emission ($L_{PT\ crs}$)during the constant speed test is on average 4 dB(A) lower than the rolling noise emission:

$$L_{PT\ crs} = L_{roll\ crs} - 4\ \text{dB(A)}$$

Based on the summation formula:

$$L_{crs\ rep} = 10.lg(10^{(L_{PT\ crs}/10)} + 10^{(L_{roll\ crs}/10)}$$

One can derive that:

$$L_{roll\ crs} = L_{crs\ rep} - 1{,}46\ \text{dB(A)}$$
$$\approx L_{crs\ rep} - 1{,}5\ \text{dB(A)}$$

The second assumption is that the rolling noise during the WOT test at 50 km/h is equal to the rolling noise during the constant speed test at 50 km/h:

$$L_{roll\ wot} = L_{roll\ crs}$$

In that case is the power train noise during the WOT test:

$$L_{PT\,wot} = 10.lg(10^{(L_{wot\,rep}/10)} - 10^{(L_{roll\,wot}/10)}$$
$$= 10.lg(10^{(L_{wot\,rep}/10)} - 10^{((L_{crs}-1,5)/10)}$$

With the two assumptions mentioned above both the rolling noise and the power train noise in the WOT test and the constant speed test can be computed. This was done for each vehicle and the results were averaged per vehicle category. These average results are given in the left hand part of Table 46.

E.2 Prediction of tyre-road noise contribution to future test results

After this step a prediction of the effects of the future lowering of limit values for rolling noise of tyres can be given. As mentioned in 6.3.4 stricter limit values for rolling noise of tyres will be introduced starting from 1 November 2012. The reduction of the limit values is given in Table 45. For the C1 tyres a weighted average of the limit value reductions with emphasis on the mid sized tyres is 3,8 dB(A).

Table 45 - Current and future limit values for tyre rolling noise.

Class limit values - Old				Class limit values - New					Reduction
Tyre class	**Nominal section width**		**Limit value**	**Tyre class**	**Nominal section width**		**Limit value**		**Limit values**
C1a	≤ 145		72				70		-2
C1b	> 145	≤ 165	73				70		-3
C1c	< 165	≤ 185	74	C1A	≤ 185		70		-4
C1d	> 185	≤ 215	75	C1B	> 185	≤ 215	71		-4
C1e	> 215		76	C1C	> 215	≤ 245	71		-5
			76	C1D	> 245	≤ 275	72		-4
			76	C1E	> 275		74		-2
Weighted average C1 tyres									**-3,8**
Tyre class	Category of use		Limit value	Tyre class	Category of use		Limit value		Limit values
C2	Normal		75		Normal		72		-3
C2	Snow		77		Traction		73		-4
C3	Normal		76		Normal		73		-3
C3	Snow		78		Traction		75		-3
Average C2 and C3 tyres									**-3,3**

A third assumption is that the reduction of the rolling noise limit values will lead after a transition period of a couple of years to a downward shift of the noise emission values of the complete tyre population available on the market. Also it is assumed that this downward shift will be equal to the average reduction of the limit values. So, after the transition period the average rolling noise emission value of C1 tyres will be 3,8 dB(A) lower than before the introduction of the lower limit values.
The lower limit values will be in force for new types of tyres that will be introduced on the market after 1 November 2012. Vehicles that will be subjected to a noise emission test after this date can be equipped with tyres that have a 3 to 4 dB(A) lower rolling noise emission than the current average. This means that the rolling noise contribution during the WOT and the constant speed test will be reduced.
The fourth assumption is that these future rolling noise contributions will be reduced with 3,8 dB(A) relative to the current rolling noise contributions:

$$L_{roll\,crs\,2013} = L_{roll\,wot\,2013} = L_{roll\,wot} - 3,8$$

If the power train noise contribution would remain unchanged one can derive the following relations:

$$L_{PT\,wot\,2013} = L_{PT\,wot}$$

$$L_{PT\,crs\,2013} = L_{PT\,crs}$$

$$L_{wot\,rep\,2013} = 10.lg(10^{(L_{PT\,wot\,2013}\,/10)} + 10^{(L_{roll\,wot\,2013}\,/10)}$$
$$= 10.lg(10^{(L_{PT\,wot}\,/10)} + 10^{((L_{roll\,wot} - 3{,}8)/10)}$$

$$L_{crs\,rep\,2013} = 10.lg(10^{(L_{PT\,crs\,2013}\,/10)} + 10^{(L_{roll\,crs\,2013}\,/10)}$$
$$= 10.lg(10^{(L_{PT\,crs}\,/10)} + 10^{((L_{roll\,crs} - 3{,}8)/10)}$$

The last two equations describe the results of the two tests that merge together into the predicted final test result $L_{urban\,2013}$:

$$L_{urban\,2013} = L_{wor\,rep\,2013} - k_p.(L_{wot\,rep\,2013} - L_{crs\,rep\,2013})$$

Where k_p is supposed to be equal to the value in the current tests, and may be derived from:

$$k_p = \frac{L_{wot\,rep} - L_{urban}}{L_{wot\,rep} - L_{crs\,rep}}$$

The predicted value of $L_{urban\,2013}$ would be the test result if only the rolling noise limit values would become stricter, without a reduction of the vehicle noise emission limit values. Therefore this predicted value indicates to what extent the type approval test results will reduce without any effort for noise emission reduction of the power train, thanks to the upcoming stricter tyre noise regulations.

The estimated values of the quantities discussed above for the relevant vehicle categories are given in the right hand part of Table 46.

Vehicle category	total number	Lurban average method B	Lwot-rep method B average	Lcrs-rep method B average	Lroll-crs = Lroll-wot average	LPT-crs average	LPT-wot average	kp average	Lroll-crs = Lroll-wot > 2012	Lcrs-rep >2012	delta Lcrs-rep 2010 - >2012	Lwot-rep >2012	delta Lwot-rep 2010 - >2012	Lurban > 2012	delta Lurban 2010 - >2012
		[dB(A)]							[dB(A)]						
M1	647	70,0	70,8	68,1	66,6	62,6	68,3	0,29	62,8	65,7	-2,4	69,4	-1,4	68,3	-1,7
M1G	24	71,0	71,7	68,7	67,2	63,2	69,6	0,25	63,4	66,3	-2,4	70,5	-1,2	69,5	-1,5
M2 <3,5t	12	71,8	72,4	69,8	68,3	64,3	70,3	0,25	65,0	67,7	-2,1	71,4	-1,0	70,5	-1,3
N1	52	72,0	72,5	70,2	68,7	64,7	70,0	0,21	64,9	67,8	-2,4	71,1	-1,4	70,4	-1,6
N1G	3	74,2	74,4	71,7	70,2	66,2	72,3	0,09	66,4	69,3	-2,4	73,3	-1,1	73,0	-1,2
N2	3	71,7	72,6	70,6	69,1	65,1	69,2	0,47	65,9	68,5	-2,1	70,8	-1,8	69,8	-1,9

Table 46 - Overview of current and future power train and rolling noise contributions and effects of reduction of rolling noise limit values on method B test results.

F Example of the database file format

Monitoring Procedure

according to EC Directive 70/157/EEC and UN/ECE Regulation 51

Information to be communicated to the European Commission
Mailbox: entr-noise-monitoring-procedure@ec.europa.eu

Vehicle										
Trade mark			Vehicle type (commercial name)*				Model year			
Categorie					Identification no.					
Body type					Off Road Vehicle (Y/N)					
Engine type					Engine Capacity (cm³)					
Engine power $_{max}$ (kW)		at		rpm	$P_{max\ 3/4}$ (rpm)			$P_{max\ 1/2}$ (rpm)		
Engine torque $_{max}$ (Nm)		at		rpm	Engine position					
Gearbox type	MT / AT		No. of axles				No. of driving axles			
No. of gears			Drive axle				Axle ratio			
Gear										
Gear ratio										
Vehicle mass measurement Method A (kg)					PMR Method A (kW/t) (1)					
Vehicle mass measurement Method B (kg)					PMR Method B (kW/t) (1)					
Vehicle length (m)					Partial Power Factor kp					
Axle 1	Tyre mark				Tyre type			Tyre size		
Axle 2	Tyre mark				Tyre type			Tyre size		
Axle 3 (if applicable)	Tyre mark				Tyre type			Tyre size		
Axle 4 (if applicable)	Tyre mark				Tyre type			Tyre size		
Axle 5 (if applicable)	Tyre mark				Tyre type			Tyre size		

Noise Reduction System					
Insolation		Engine hood		Below engine	
Pre-Katalyst		Main-Katalyst		DPF	Resonator
Intake silencer		Centre silencer		Rear silencer	
Noise shields under chassis (if applicable)			Noise shields above chassis (if applicable)		
Noise shields under cab (if applicable)			Noise shields behind cab (if applicable)		
Exhaust System Drawing No.			Further noise shields (if applicable)		

Stationary vehicule noise L_{stat} (dB(A))(2)
Comment :

(1) For M_1, N_1, M_2 < 3,5 t
(2) If results differ between method A and B, both values shall be indicated

* Please note that “vehicle type” refers to the manufacturer type code and preferably to the commercial name of the vehicle, but not to internal codes.
}}}

METHOD A
(old measurement method according to Annex 3)

Test Track		Date	
Absorption Factor		Void content	
Calibration of analyser	Target (dB(A))	Actual before (dB(A))	
		Actual after (dB(A))	
Ambient conditions		Ambient noise (dB(A))	
Air Temperature (°C)		Test track temperature (°C)	
		Air pressure (hPa)	
Wind speed (m/s)		Wind direction (°)	
		Air humidity (%)	

Measurement

Gear selected	Run	$V_{AA'}$ Target	L max left *	L max right *	$V_{AA'}$	$N_{AA'}$ / S	$V_{BB'}$	$N_{BB'}$ / S	Intermediate result (Maximum)
		kph	dB(A)/E	dB(A)/E	kph	%	kph	%	dB(A)/E
	1								
	2								
	1								
	2								
	1								
	2								
	1								
	2								
	1								
	2								
	1								
	2								

Final result (dB(A)/E) :	**Limit value (dB(A)/E) :**

* measured value - 1dB(A)

}}}

METHOD B
(new measurement method according to Annex 10)

Test Track		Date	
Absorption Factor		Void content	
Calibration of analyser	Target: (dB(A))	Actual before (dB(A))	
		Actual after (dB(A))	
Ambient conditions		Ambient noise (dB(A))	
Air Temperature (°C)		Test track temperature (°C)	
Air pressure (hPa)			
Wind speed (m/s)		Wind direction (°)	
Air humidity (%)			

Measurement			
Tested Vehicle weight (kg)		Vehicle load (kg) (2)	
Gear selected (i) (1)		Gear selected (i+1) (1)	
Target acceleration a_{urban} (m/s²) (1)		Reference acceleration $a_{wot\ ref}$ (m/s²) (1)	
Achieved acceleration $a_{wot\ test}$ (m/s²) (1)		kp (1)	
k (1)			

Gear selected	Run	WOT								CRS (1)	
		L max left	**L max Right**	$V_{AA'}$	$V_{PP'}$ (1)	$V_{BB'}$	$N_{BB'}$ *	a wot (1)	Pos. of pre-acceleration from AA' (1)	**L max left**	**L max Right**
		dB(A)	dB(A)	kph	kph	kph	rpm	m/s²	m	dB(A)	dB(A)
	1										
	2										
	3										
	4										
	1										
	2										
	3										
	4										

Intermediate Result (1) :	L_{WOTRep} (dB(A))	L_{CRSRep} (dB(A))	
Final Result (1) :	L_{URBAN} (dB(A))	**Final Result (2) :**	L (dB(A))

(1) For M1, N1, M2 < 3,5 t
(2) For M2 > 3,5 t, M3, N2, N3

* Please note that engine speed (n BB') is required for M1 and N1 vehicles.

}}}}