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New EU and UN/ECE Vehicle noise emission limits and associated measurement methods

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ABSTRACT
In 2013 or early 2014 the European Union will decide upon a new "Regulation on the sound level of motor vehicles". It will specify a new type approval test method for noise emission and will give revised limit values for the permissible noise emission per vehicle (sub-)category. The new regulation may be seen as a final stage of a long series of developments towards a more representative way of testing, but at the same time it should be a starting phase of regular reductions of limit values in future in order to achieve a substantial reduction of traffic noise impact and improvement of urban environmental conditions. In this paper the historical development of noise emission test methods, the shortcomings of the current test method and the expected improvements resulting from the new test method are discussed. The possible effects of three alternative proposals for the revision of the limit values and an outlook to future developments concerning vehicle noise emission test methods are presented.
Keywords: Noise emission, road vehicles, measurement method

1. INTRODUCTION
On December 6, 2011 the European Commission (EC) issued a Proposal for a Regulation of the European Parliament and of the Council on the sound level of motor vehicles [1]. After acceptation this regulation will replace the Directive 70/157/EEC [2] that has been the basis for legislation on vehicle noise emission in the EU member states since 1970. The new regulation proposes the introduction of a fundamentally revised measurement method for the noise emission of road vehicles and a revised set of limit values that regulates the permitted noise emission of road vehicles of all categories and subcategories. Since the publication of the proposal, the European Parliament (EP) has studied, discussed and amended the proposed requirements. On February 6, 2013 the EP has voted on the amendments in first reading [3]. In the process on decision making after that step it was the turn of the Council of the EU (the Ministers of the Member States) to consider the proposal and to amend or accept the earlier positions of the EC and the EP. Depending on how soon a compromise between the different points of view can be reached, the process of decision making may take another year before the final formulation of the legislation will have been established.

The basic reason for the revision is that during the long period of existence of vehicle noise regulations no reduction of the average noise emission in traffic of individual passenger cars has been achieved, in spite of the fact that in this period the type approval limit values for noise emission have been lowered with 8 dB(A) (see Figure 1; ref[13]). For trucks the situation is somewhat more favorable: an average reduction of 4 - 5 dB(A) in traffic has been obtained, while the reduction of the

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limit values was 11 - 12 dB(A). In section 2.3 these facts will be discussed in more detail.

The duration of the decision making process may seem long, but it is actually rather short compared to the period of preparation of the revision that preceded the proposal of December 6, 2011. In this paper the history of the European vehicle legislation with respect to noise emission will be discussed and explained, and interpreted from an acoustical point of view.

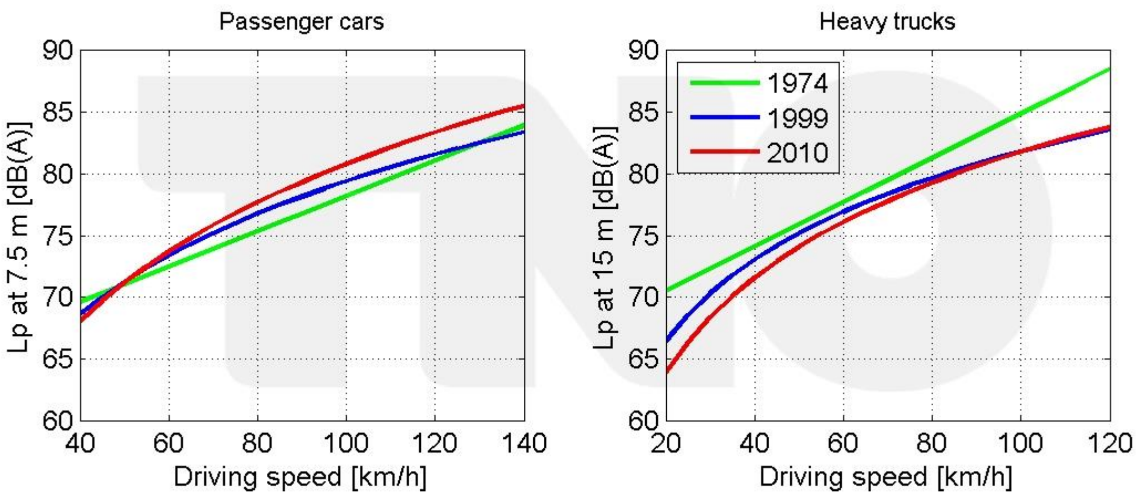

Figure 1 - Comparison of in-traffic noise emission of passenger cars and trucks in The Netherlands in 1974, 1999 and 2010 [13].

2. HISTORY OF THE VEHICLE NOISE EMISSION REGULATIONS

2.1 Intentions of the original Directive

The original motivation in the years before 1970 to issue a Council Directive “on the approximation of laws of the Member States relating to the permissible sound level and exhaust system of motor vehicles” was not based on considerations of environmental management, but mainly on the need to harmonize the legislation in the EU Member States. In the preamble of the Directive it is clearly stated that it was primarily driven by economic considerations aimed at removing trade barriers. It specified seven vehicle categories and the prescribed test method was as simple as possible. This method was copied from ISO Recommendation 362, dating from 1961[4a]. This recommendation was replaced by an ISO standard in 1981 [4b]. As stated in the scope of this standard, “the method was designed to meet the requirements of simplicity as far as they were consistent with reproducibility of results and realism in the operating conditions of the vehicle.” The specifications were intended “to reproduce the noise levels in urban traffic flow of irregular character which requires the use of intermediate gears with full utilization of the engine power available.” These statements express clearly that the aim of the test was to measure the maximum noise levels that could be produced by the vehicle drive line in urban traffic conditions.

The basic test conditions were full throttle acceleration at approximately 50 km/h in second gear (for a two- three- or four-speed gear box) or in third gear (for a gear box with more than four gears). In this way of testing the contribution of tyre/road noise to the test results was of minor importance. The limits values specified were aimed at regulating the maximum noise levels, and not the average noise emission in traffic. Therefore the first set of limit values did not have much impact on the actual noise emission of the road vehicles in practice, and served primarily as a ceiling for excessively high noise levels.

2.2 Modifications and revisions to the Directive

After the introduction in 1970 the principles of the Directive and the details of the test method were changed repeatedly. The most relevant modifications, amendments and notes are:

- Dir. 81/334/EEC that came into force between 01/01/1982 and 01/10/1985 required that light vehicles with more than four gears were to be measured in 2nd and 3rd gear, from which the results were averaged to a single overall level [5].

- Dir. 84/372/EEC that came into force between 01/10/1984 and 01/10/1986: Powerful cars with more than 140 kW, > 75kW/t and a minimal achieved speed of 61 km/h over the test section by the microphone should only be measured only in 3rd gear. The procedure for vehicles with automatic gearboxes was also adapted [6].
- Dir. 92/97/EEC that came into force between 01/07/1993 and 01/10/1996 [7] specified the test track according to the ISO 10844 standard [8]. Previously, all types of road surfaces were allowed, including absorbing ones.
- Dir. 96/20/EC that came into force between 01/10/1996 and 01/01/1997 allowed the use of test tyres with a minimal tread depth of 1,6 mm [9].
- Dir. 99/101/EC that came into force between 01/04/2000 and 01/10/2000, concerning the use of replacement silencers [10].
- An extra 1 dB(A) is allowed to compensate for measurement inaccuracy. Vehicles with off-road capabilities, vehicles with a direct injection Diesel engine and the ‘powerful cars’ (see second bullet above) have another extra 1 dB(A) allowance.

The specified limit values changed four times as indicated in Table 1.

Table 1 - Historical overview of the development of the type approval noise limit values for new road vehicles since the official introduction in 1970.

	EU Directive	**70/157/EEC**	**77/212/EEC**	**84/424/EEC**	**92/97/EEC**
	Year of enforcement	1970	1977 - 1982	1985 – 1990	1993 – 1996
Vehicle category		**Limit value in dB(A)**			
Passenger car		82	80	77	74
Delivery van and minibus	Max mass ≤ 2 tons	84	81	78	76
	Max. mass >2 tons ; ≤ 3,5 tons	84	81	79	77
Buses > 3,5 tons	Rated power < 150 kW	89	82	80	78
	Rated power ≥ 150 kW	91	85	83	80
Trucks > 3,5 tons	Rated power < 75 kW	89	86	81	77
	Rated power ≥ 75 kW; < 150 kW	89	86	83	78
	Rated power ≥ 150 kW	91	88	84	80

2.3 Investigations into the effect of type approval testing

Although the requirements had been introduced for the purpose of harmonization of the vehicle regulations in the different EU Member States, sometime later also environmental considerations began to play a role and several member states saw the vehicle noise Directive as a tool for controlling and reducing the noise emission of road vehicles. The expectations were that by lowering the limit values for the type approval test also the in-traffic noise emission of road vehicles would be reduced.

In the period from 1985 until 2000 in several Member States, e.g. Germany and The Netherlands, measurement campaigns were organized to compare the noise emission levels of individual vehicles of the newest generations with the values that were known from the past [11], [12]. Soon it was observed that the noise emission of vehicles in traffic did not decrease at the same rate as the reduction of the limit values. Research was started to investigate the reasons for this discrepancy. Results of type approval tests, according to different test methods were compared with results of representative urban drives.

In The Netherlands 103 passenger cars were included in the study [14]. The noise emission in urban drive was measured by registering during the drive the operating conditions of the vehicle and the engine (vehicle speed, engine speed, throttle valve position, gear position). For every combination of operating parameters the noise emission levels were measured on a test track at 7,5 m distance from the driving line. By using the data base of noise levels and operating conditions the registered operating parameters during the urban drive courses could be converted to momentary noise levels and from these the $L_{A,eq}$ values for the complete route could be determined. The urban route consisted of three sections: urban motorway (7,9 km; 70 – 100 km/h), suburban section (13,9 km; 50 km/h) and city center section (13,6 km; 30 – 50 km/h). On the test track also the type approval tests were executed according to three different test protocols: ISO/R 362 (testing in 2nd gear) [4a], ISO 362:1981 testing in 2nd and 3rd gear) [4b] and ISO 7188 [15]. This last ISO standard had been developed as an alternative for ISO 362. It tested the noise emission not only during full throttle acceleration in 2nd gear, but also at constant speed and was considered to be more representative for average urban driving. According to the scope of the method it was supposed to reproduce the noise level that was exceeded during only 5% of the total driving time in urban traffic flow of irregular character.

In the analysis of the data, the correlations between the $L_{A,eq}$ of the urban drive and the three type approval test results were determined. These were as given in Table 2, together with the results of a similar study, executed by FIGE in Germany [16], [17].

Table 2 – Correlation coefficients between equivalent sound levels $L_{A,eq}$ of representative urban drives and type test results according to different test protocols

Research	**Type approval test method**	**Correlation coefficient between urban $L_{A,eq}$ and type test result**
Netherlands – TNO 1981 - 1989 (103 cars)	ISO/R 362: 1961	0,20
	ISO 362: 1981	0,55
	ISO 7188:1985	0,64
Germany – FIGE 1981 - 1984 (17 cars)		
	ISO 362: 1981	0,63
	ISO 7188:1985	0,89

Although the values of the correlation coefficients in the Dutch and in the German study do not correspond very well, it is evident that the test method of ISO 7188 gave the best correlation between type approval test results and in-traffic noise emission levels.

In the 1990's the International Institute of Noise Control Engineers (I-INCE) formed an international working party to carry out a comprehensive study into the effect of regulations on the noise emissions of road vehicles. The final report of this working party [18] appeared in 2001 and confirmed most of the earlier conclusions and summed up the reasons for the limited effectiveness of the regulations:

- Limit values in the first years were not strict enough to have an impact on the actual noise emission in practice, due to the fact that the Directive was meant to regulate the maximum noise emission and not the average emission in traffic;
- The time delay effect of introduction of less noisy vehicles. As the average lifetime of vehicles is 10-15 years it takes a long time before the vehicles of a certain generation are fully replaced by vehicles of a newer generation. Moreover, as the equivalent noise levels of traffic flows are mostly influenced by the more noisy vehicles, a noticeable decrease of the average noise emission can only occur if a considerable proportion of the vehicles is of the less noisy newer generation.
- The trend towards bigger, heavier and more powerful vehicles counteracts the effects of reduction of noise emission per vehicle. Bigger, more powerful vehicles usually produce more noise than lighter, less powered vehicles. This partly compensates the gain that can be achieved by lowering the type approval limit values. This trend occurs for nearly all vehicle categories, for passenger transport as well as goods transport.
- Lack of control of noise emission over the service life of vehicles. Due to technical degradation over time and to modification of noise reducing provisions (e.g. exhausts) during maintenance activities the noise emission of vehicles may rise after being put into service. As no effective control of noise emission of vehicles during their service life exists in most countries such increase of the noise emission will not be controlled. For 'low noise' vehicles this effect may larger than for 'untreated' vehicles.
- Lack of relevance and representativeness of the test method. As argued before, the test method according to ISO 362 was primarily aimed at measuring the maximum noise emission of a

vehicle, and not its average in-traffic noise emission. The test conditions, even after the introduction of testing in two gears in 1981, were not very relevant for the normal noise emission and represented only a small percentage of all possible vehicle operating conditions. Especially the lack of a constant speed condition leads to a disregard of the contribution of tyre/road noise to the effective noise emission in traffic.

- Disregard of tyre/road noise creates a lower limit to the reduction of average noise emission. As argued above the tyre/road noise does hardly contribute to the test results of the type approval tests. Therefore the noise production of the tyres is not influenced by the type approval limit values. If the various components of the drive line are modified to comply with stricter limit values, while the tyre/road noise remains unchanged, this creates a lower limit for the reduction of the average in-traffic noise emission.

In addition to the conclusions from the I-INCE report one other important factor should be mentioned:

- At several points in time the test method was modified in such a way that the results of the test changed in a downward direction for certain categories of sub-categories of vehicles. A strong example of such a modification is the introduction in 1982 of testing light vehicles with more than four gears in 2nd and 3rd gear and to average the results of the two partial tests. The effect was that the measured noise emission result of all passenger cars and light vans decreased. However, this change was not implemented in the limit values that were in force at that time, which implied that the limit values became effectively less strict than before. Also the changes in the test method for high powered cars and the permission to test with tyres with a minimal tread depth had a downward effect on the test results, which was not compensated for by adapting the limit values.

2.4 Further developments aimed at achieving a more representative test method

In the early 1990's the facts and conclusions discussed above had become known. ISO Technical Committee 43 'Acoustics', that had been responsible for the development of ISO 362 and ISO 7188 in the past, decided to install a new Working Group 42 that should review the existing test methods and develop a method that could be the basis for a more relevant and representative way of testing. This WG started its work in 1993 and is actively involved in the development of test methods until today.

A year after the start of the work, WG 42 published in 1994 a revised version of ISO 362 [4c] with some minor updates, the most important of which was the reference to ISO 10844 [8], specifying the standardized test track. In the period after this quick update the WG focused on improving the repeatability and reproducibility of the test method without fundamentally changing the principle of the test, being full throttle acceleration in intermediate gears. As a result of this process in 1998 another revised version [4d] was published, that contained changes concerning the specification and calibration of measurement equipment, the description of the vehicle conditions during the test and the specification of the allowable meteorological conditions. Also the text of the standard was lined up with the prescribed test method in the EC Directive 96/20/EEC [9], e.g. by allowing test tyres with minimal tread depth.

In the meantime the fundamental reconsideration of the test method had started. This could have been the moment to introduce a radical change and to follow the example of the fuel efficiency test method for vehicles. This would imply that a representative urban drive cycle would be defined, based on simulating the actual noise emission levels during urban driving. The test would then no longer be carried out in outdoor conditions on a test track, but in a laboratory environment, where the climate conditions could be controlled and the varying engine load of an urban drive cycle would be realized on a dynamometer test bench. This approach could even open the possibility to fully separate the testing of drive train noise and of tyre/road noise by executing the noise test during the urban drive cycle without rolling tyres on a dynamometer drum, but by simulating the engine load fully by coupling the drive train to a chassis dynamometer. The tyre/road noise could then be tested in separate tests, either on a test track or on a laboratory drum test bench. Suggestions to aim the developments at this goal were not adopted by the majority of the WG, because they held the opinion that the test should be executed on the complete vehicle, in a test set-up that would not require too high investments and could be easily operated by industry, regulatory bodies and test laboratories. The conclusion was that the test should continue to be based on a pass-by of a vehicle driving on a test track.

In line with the findings from the 1980's [14], [16] it was decided to choose the principle of ISO 7188 as the most suitable for a new test method for light vehicles (passenger cars and light vans). The constant speed part of that test method would be representative for constant speed free flow traffic in urban environments, but the full throttle acceleration part was not very representative for normal acceleration at urban intersections. After extensive study and testing the ACEA (European Automobile Manufacturers' Association) submitted a proposal that combined the ease of operation of a full throttle acceleration test with a more sophisticated tuning of the operating conditions to realistic vehicle characteristics. The methodology is as follows:

- From the power-to-mass ratio (PMR) of the vehicle a target acceleration a_{urban} is derived that the vehicle is supposed to achieve under partial power conditions in urban traffic at 50 km/h.
- Furthermore a reference acceleration $a_{wot,ref}$ is derived from the PMR that the vehicle shall achieve under wide open throttle (WOT) conditions. This reference acceleration has to be achieved on the usual 20 m test track starting from an entry speed of 50 km/h.
- The partial power factor k_p expresses the ratio between the target and the reference acceleration, and is calculated as follows:

$$k_p = 1 - \frac{a_{urban}}{a_{wot,ref}} \qquad (1)$$

- If the reference acceleration can be realized in one particular gear, the test shall be carried out in that gear. If the reference acceleration cannot be realized in one single gear, two gears shall be employed, one that gives a greater acceleration than the reference value and one that gives a lower acceleration.
- The noise emission result of the double WOT test is an interpolation of the two partial noise emission results, interpolated according to the value of the reference acceleration relative to the acceleration interval between the two gears.
- One or two noise emission cruise by tests at a constant speed of 50 km/h are carried out in the same gears as used for the WOT test.
- The noise emission result of the double cruise test is an interpolation between the two partial results, interpolated in the same way as the WOT results.
- The final test result L_{urban} is an interpolation between the WOT test result and the cruise test result, interpolated according to the partial power factor (1). The total composition of the final result is shown in Figure 2.

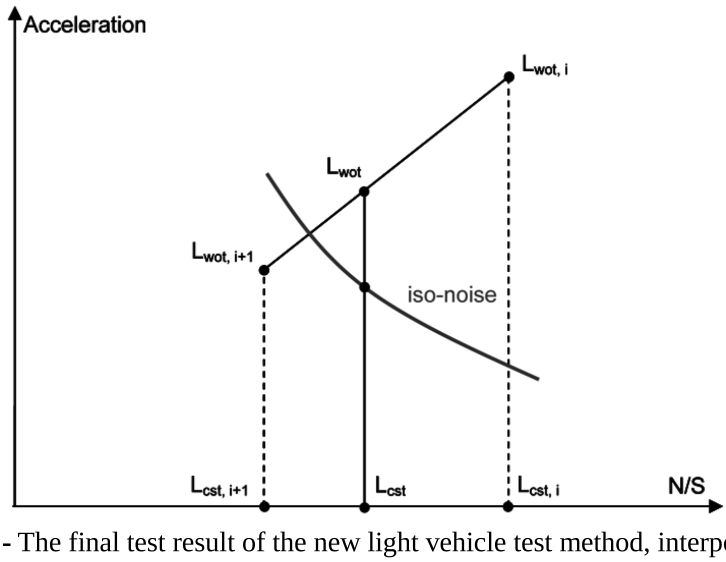

Figure 2 - The final test result of the new light vehicle test method, interpolated between four partial results [4e]

By using a mix of WOT test results and cruise by test results the final result is supposed to be representative for the noise emission during partial power acceleration at approximately 50 km/h in intermediate gears. According to investigations of urban traffic patterns a speed of approximately 50 km/h may be considered as the most frequently occurring [19], while partial power acceleration on urban main streets is the condition that contributes most to traffic noise disturbance and annoyance [20]. Testing at partial power conditions is very difficult to execute and reproduce. Therefore the seemingly rather complex test procedure of two WOT tests and two cruise by tests is an attempt to realize a representative as well as reproducible test procedure.

For heavy vehicles the modifications of the test procedure in the revised standard ISO 362 were far less radical than for light vehicles. The principle of the test continued to be testing at WOT conditions in various intermediate gears. The most important change was that heavy vehicles would be tested in partly laden instead of unladen condition. This change was intended to prevent the generation of abnormal tyre/road noise that could occur by slip of the driven wheels under high torque without sufficient loading on the drive axle.

2.5 Monitoring period for the new test method

After publication of this new test method by ISO [4e] the method was submitted to the GRB group (Groupe Rapporteur Bruit = Working Party on Noise) of the UNECE (United Nations Economic Commission for Europe). This group of experts conducts research and analysis to develop noise requirements for vehicles and prepares regulatory proposals on noise to WP.29.

WP.29 is a permanent working party in the institutional framework of the United Nations that works as a global forum for open discussions on motor vehicle regulations. Any member country of the United Nations and any regional economic integration organization, set up by country members of the United Nations, may participate fully in the activities of the World Forum and may become a contracting party to the Agreements on vehicles administered by the World Forum. Governmental and non-governmental organizations (NGOs) may also participate in a consultative capacity in WP.29 or in its subsidiary working groups. The European Commission as well as the EU member states participate in the GRB and employ the GRB regulations as a basis for EU Directives and regulations.

The UN-ECE GRB published the new test method in 2007, based on the revised ISO standard, 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. This monitoring period under UN-ECE Regulation No 51 [21] lasted from 1 July 2007 until 1 July 2009. In addition to this also the EC initiated a monitoring period under Directive 2007/34/EC [22] that started on 6 July 2008 and expired on 6 July 2010. During the monitoring periods the results of the old and of the new test method were submitted to the European Commission. By this procedure a database of parallel test results was collected that offered a good opportunity to investigate the qualities of the new method and to quantify the differences between the results of the two methods.

2.6 VENOLIVA study and report

2.6.1 Goal of the study and approach

At the request of the European Commission TNO has executed a study into the differences between the old 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 acronym of the study was VENOLIVA (Vehicle Noise Limit Values) [23].

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 old 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 enhanced 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 economic 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 obtained during the monitoring period with the old method A and the new method B for the different vehicle categories. This result is presented in Table 3 and Figure 3:

Table 3 - Average difference between noise emission test results according to method B and method A per vehicle category

Category	**Description**	**Total number of vehicles in database**	**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**

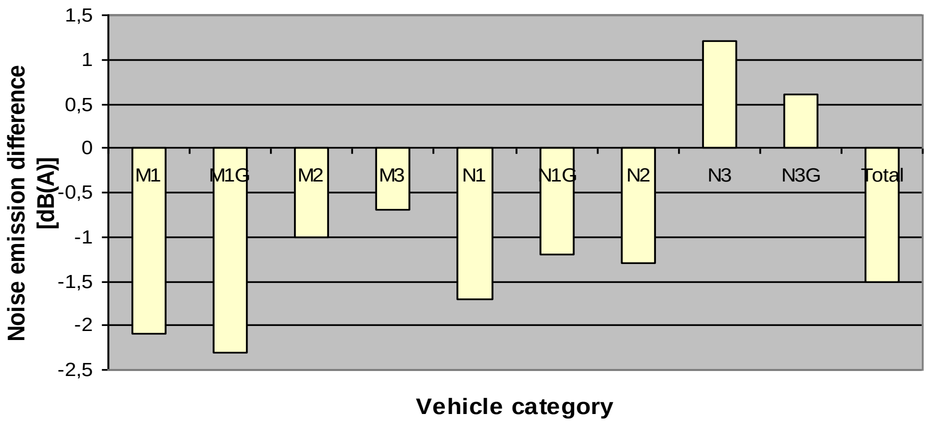

Figure 3 - Average difference between the test results of methods B and A per vehicle category.

2.6.2 Influence of tyre/road noise on vehicle noise tests

A complicating factor in the analysis of the test results was that each test result, from the old test method as well as from the new test method consists of a mix of power train and tyre/road noise contributions, because the noise emission is measured during a vehicle pass-by in which both types of noise are present. The tyre/road noise contribution will be reduced in the next decade due to the implementation of a separate EU Directive addressing the tyre rolling noise [24]. 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 rolling noise 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 rolling noise limit values will apply to all new vehicles and all new tyres. This regulation will lead to reductions of rolling noise, in traffic as well as during vehicle type approval tests. That means that the results of the vehicle noise tests will decrease in the coming years, even without any change of the limit values for vehicle noise. In the VENOLIVA study an estimated assessment was made of the average tyre/road noise contribution during the WOT tests and the cruise-by tests for passenger cars and other light vehicles [23], [25], and of the decrease of the test results that will be the effect of the stricter tyre noise limit values; see Table 4.

Table 4 - Predicted reductions of the rolling noise emission of tyres and of the vehicle noise test results due to the coming into force of the EU Regulation 661/2009 [24] in three stages starting on 1 November 2012.

[L_{roll} = the rolling noise of tyres during the cruise test; $L_{crs,rep}$ = the reported result of the cruise test; $L_{wot,rep}$ = the reported result of the WOT test; L_{urban} = is the final result of the type approval test for light vehicles]

Vehicle category	**Decrease L_{roll} after 2012**	**Decrease $L_{crs\ rep}$ after 2012**	**Decrease $L_{wot\ rep}$ after 2012**	**Decrease L_{urban} after 2012**
M1	3,8	2,4	1,4	1,7
M1G	3,8	2,4	1,2	1,5
M2 < 3,5 t	3,3	2,1	1,0	1,3
N1	3,8	2,4	1,4	1,6
N1G	3,8	2,4	1,1	1,2
N2	3,3	2,1	1,8	1,9

2.6.3 Recommendations for revised 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.

After evaluation of the results of the impact analysis (research question d.) it was recommended to implement the limit values according to Option 5. In this option the consequences of the transition to the new test method B were combined with the aim of achieving a significant reduction of vehicle noise emission in traffic in a two-step scheme. In the first step of this option the limit values for passenger cars would be lowered by 2 dB to compensate for the difference between the test methods and with 2 dB to achieve a noise emission reduction. In the second step again 2 dB reduction would be introduced. The total change would be - 6 dB in a numerical sense or - 4 dB effectively. For heavy trucks the first step would combine a raise of 1 dB for test method compensation and a lowering of 1 dB for noise emission reduction. The second step would introduce a reduction of 2 dB, giving a total change of - 2 dB numerically or - 3 dB effectively. Similarly for other categories effective reductions of 4 dB were recommended for light vehicles and buses and 3 dB for medium and heavy trucks.

3. EC proposal for a new regulation

The European Commission largely adopted the recommendations of the VENOLIVA report and issued a Proposal for a Regulation of the European Parliament and of the Council on the sound level of motor vehicles [1] on December 6, 2011. The proposal for the new regulation proposes the replacement of the old test method by the new one, with some small changes compared to the test method published by UNECE in 2007 [21]. The proposed revised set of limit values was fully in line with the VENOLIVA recommendations. In connection to the new test method also the concept of Additional Sound Emission Provisions (ASEP) was introduced. A consequence of the operating conditions of method B will be a shift from pure powertrain noise emission in the test to a mixture of both powertrain and rolling noise. Moreover, in most cases the test is executed at relatively low engine speeds, which results in lower powertrain/exhaust noise than in the old method. This introduces the risk of unregulated noise emissions at high engine speeds, when the noise emission at high engine speeds deviates strongly from the noise emitted at low engine speeds. This may be the case for powerful sports cars that have a high acceleration potential. For these cases the ASEP requirements try to control the noise at operating conditions that are not covered by the method B test. In support of these requirements a measuring method to evaluate compliance with the additional sound emission provisions was also published as an annex to the EC Proposal.

Since the publication of the proposal the European Parliament (EP) has studied, discussed and amended the proposed requirements [3]. The amendments entailed a significant weakening of the noise reduction potential of the proposed regulation. The next step in the decision making process was the consideration of the EC proposal by the Council of the EU (the Ministers of the Member States) that should result in the amendment or the acceptance of the previous versions from the EC and the EP. In May 2013 the Council Working Group prepared its own variant of the limit values table that may be seen as a compromise between the two previous versions. Besides differences between the proposed limit values per vehicle (sub-) category also differences in the implementation time schedule exist between the three versions.

At the moment of writing of this paper there is no reliable prediction of the outcome of the decision making process within the EU. It seems likely that the final result will be positioned somewhere between the EC proposal and the EU Parliament amendments.

3.1 Impact analysis of different limit value sets

In order to support the preparation of a Council decision TNO was asked to evaluate the three versions of the proposal and to analyze the impacts with the same methods as used in the VENOLIVA study. A summary of the results of this analysis [26] [27] is given in Annex A. The most ambitious of the three versions, the proposal of the EC, would result in a reduction of L_{DEN} and L_{night} noise impact levels, averaged over a variety of road and traffic types, of 2,8 dB(A). This would lead to a reduction of the number of (highly) annoyed people by approximately 20%. This reduction of the traffic noise impact would bring a socio-economic benefit of 145 Billion Euro, while the raise of the development and production costs for industry would be 6,7 Billion Euro. This implies a benefit-cost ratio of 22 and amounts to a net present value of 138 Billion Euro. Reduction of vehicle noise emission will thus yield a considerable economic benefit for the member states of the European Union.

3.2 Future changes of the limit values

The current proposal for modification of the test method and lowering of the limit values causes a great deal of political discussion and reveals rather fundamental differences of opinion between the supporters of noise abatement and the supporters of industrial interests. Nevertheless, for insiders it is very clear that the effects of this limit value reduction will only constitute a small step on the long road towards substantial reduction of the impact of traffic noise. Therefore it would be advisable to decide not just on one small step, but on a long term strategy of regular reductions of the limit values. That would offer a much clearer perspective on the improvement of the urban environment on the long run, and it would give the industry the possibility to anticipate in an early stage on future requirements and develop the most economical methods to comply with these. A recommendation to initiate such a long term strategy was included in the VENOLIVA report, but unfortunately this recommendation was not adopted in the EC proposal.

Therefore, at this moment it is very difficult to predict when the next lowering of the limit values may be expected.

4. New developments concerning vehicle noise test methods

Some years ago a concern arose about the low noise emission of electric and hybrid vehicles. When driving at low speeds in electrical drive mode these vehicles may be almost inaudible. This might the cause of traffic accidents, when pedestrians or bicyclists do not hear an approaching vehicle. In particular visually impaired people were worried by this new threat of traffic participation. As a result of the concern raised by organizations of blind and visually impaired persons, several states of the USA initiated new legislation, demanding a minimum noise emission during low speed driving and standstill. These new legal requirements were supported by the development of a standard specifying a test method for minimum noise emission of vehicles by the SAE. With the aim to attain international harmonization on this topic it was submitted for discussion to the GRB of UNECE. Also a new work item proposal for the development of an ISO standard on testing of minimum noise emission was submitted to ISO TC 43/ SC 1. Several ISO member bodies objected to the proposal because developing such a method would pave the way for introducing international requirements for a minimum noise production of road vehicles and would counteract the aim of achieving lower noise emission of road vehicles. In spite of these objections the proposal was accepted by ISO TC43 and allocated to WG 42. Since 2009 a subgroup is working on the drafting of a test method (ISO 16254) that bears a strong resemblance to the test method of the old ISO 362. It will be based on outdoor testing on the same test track as used for type the approval tests of the (maximum) noise emission.

However, as the minimum noise levels are significantly lower than the noise emission during the type approval tests, the minimum noise test is much more sensitive to disturbing background noise than the normal noise test. That observation has triggered another new development in vehicle noise testing: the development of an indoor vehicle noise test procedure aimed at achieving an acoustical correlation between exterior noise testing in a free-field anechoic test chamber and real outdoor testing. Another subgroup of WG 42 is working on this item since 2010. This development is aimed to achieve a perfect imitation of the classic pass-by test in an indoor test environment. The acceleration of the vehicle over a distance of 20 m on the test track is simulated on a dynamometer drum and transient sound signal on the stationary microphone in the middle of the test track during the passage of the vehicle is simulated by scanning the signals received by an array of microphone positioned at regular intervals along the test rig. In the opinion of the author this is a missed chance: the development of an indoor test method offers the possibility to create a fundamental change and to introduce an advanced test method based on an urban drive cycle (as described in section 2.4). Instead, the subgroup focusses on imitating a test method with a rather simple set of operating conditions that still suffers from many limitations and drawbacks (e.g. the need for ASEP).

5. CONCLUSIONS

The new EU and UN/ECE vehicle noise emission limits and associated measurement methods may be seen as a final stage of a long series of developments towards a more representative way of testing, but at the same time it should be a starting phase of regular reductions of limit values in future in order to achieve a substantial reduction of traffic noise impact and improvement of urban environmental conditions.

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ANNEX A – IMPACT ANALYSIS OF VARIOUS LIMIT VALUE SETS

The consequences of the proposals from the European Commission (EC), the EU Parliament and the Council of Ministers for environmental noise impact, noise annoyance, sleep disturbance and economical factors were analysed in support of the preparation of a decision of the Council [27]. The results of the analysis are presented in this Annex with the current situation as a reference.

The estimated reductions of the maximum noise emitted by a single passing accelerating vehicle are given in Table A.1.

Table A.1 - Effect of the EC, the EU parliament and the Council proposals on the reduction of the maximum noise emitted by a single passing accelerating vehicle

ΔLmax [dB(A)]	**Cars**	**Vans**	**Buses**	**Lorries**	**HDVs**	**Average**
Current situation	0,0	0,0	0,0	0,0	0,0	**0,0**
EU Parliament	4,4	3,7	1,5	0,3	-0,3	**1,9**
Council	3,2	3,9	3,3	1,3	1,5	**2,6**
EC	4,6	4,4	4,0	2,0	2,0	**3,4**

In the Table A.2 the consequences of the different limit value sets are shown for the average environmental noise impact caused by traffic, expressed in terms of L_{DEN} and L_{night}. The average noise reductions over the eight road and traffic types for L_{DEN} are 1,9, 2,4 and 2,8 dB(A) for the EU Parliament, Council and EC proposals. These estimated noise reductions are somewhat less than the reductions for the single vehicle acceleration noise, because the noise emitted by free flowing traffic is to a larger extent determined by tyre-road noise. This type of noise will be reduced regardless of the vehicle noise limit values as a result of the tyre rolling noise regulation [24] that is already coming into force in a stepwise implementation starting from November 2012 and acts as an equalising factor between the different proposals.

Table A.2 - Differences in L_{DEN} and L_{night} of various limit value proposals of the EC, the EU Parliament and the Council relative to Current situation.

ΔL_{DEN} [dB(A)]	**Residential street - Intermittent traffic**	**Residential street - Free flowing traffic**	**Main street - Inter-mittent traffic**	**Main street - Free flowing traffic**	**Arterial road**	**Urban Motor Way**	**Rural Motor Way**	**Rural Road**	**Average**
Current situation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**
EU Parliament	2,2	1,7	2,6	1,8	1,7	1,7	1,9	1,5	**1,9**
Council	2,7	2,4	2,8	2,3	2,3	2,3	2,4	2,2	**2,4**
EC	3,7	2,7	3,8	2,5	2,5	2,5	2,5	2,4	**2,8**
Δ*Lnight* [dB(A)]									
Current situation	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**
EU Parliament	1,6	1,4	2,2	1,6	1,7	1,6	1,8	1,4	**1,7**
Council	2,4	2,3	2,6	2,3	2,3	2,3	2,4	2,2	**2,3**
EC	3,3	2,8	3,6	2,5	2,5	2,5	2,5	2,4	**2,8**

In Table A.3 and Figures A.1 and A.2 the consequences of the amendments are shown for the number and the distribution of (highly) annoyed and (highly) sleep disturbed people.

Table A.3 - Millions of (highly) annoyed and (highly) sleep disturbed people for different limit value proposals of the EC, the EU Parliament and the Council – Differences relative to current situation

Annoyance	**Millions Highly Annoyed**	**Millions Annoyed**	**Differ-ences MHA**	**Differ-ences MA**	**Relative Differ-ences MHA**	**Relative Differ-ences MA**
Current situation	54,9	118,9	0	0	0%	0%
EU Parliament text	46,1	104,1	-8,8	-14,8	-15,9%	-12,4%
Council	43,9	100,1	-11,0	-18,8	-20,0%	-15,8%
EC	42,2	96,9	-12,7	-22,0	-23,2%	-18,5%
Sleep disturbance	**Millions Highly Sleep Disturbed**	**Millions Sleep Disturbed**	**Differ-ences MHSD**	**Differ-ences MSD**	**Relative Differ-ences MHSD**	**Relative Differ-ences MSD**
Current situation	26,6	59,8	0	0	0%	0%
EU Parliament text	23,7	54,3	-2,9	-5,5	-10,7%	-9,2%
Council	22,6	51,9	-4,0	-7,9	-14,9%	-13,3%
EC	22,0	50,4	-4,6	-9,4	-17,4%	-15,7%

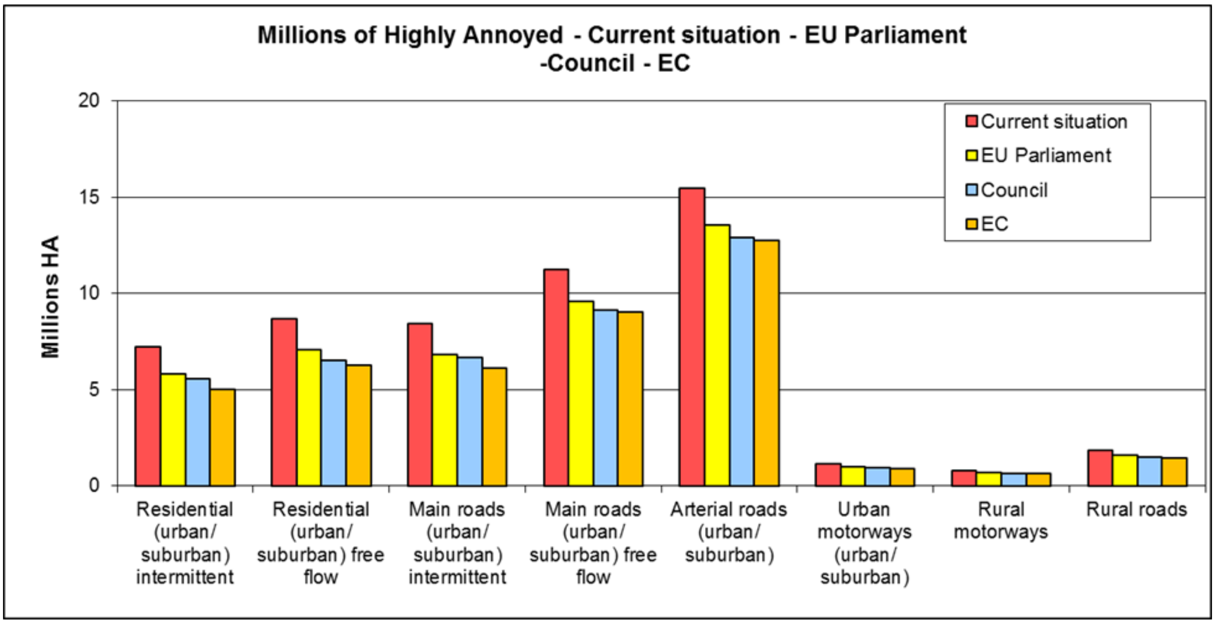

Figure A.1 – Distribution of the millions of highly annoyed people according to the type of road and traffic.

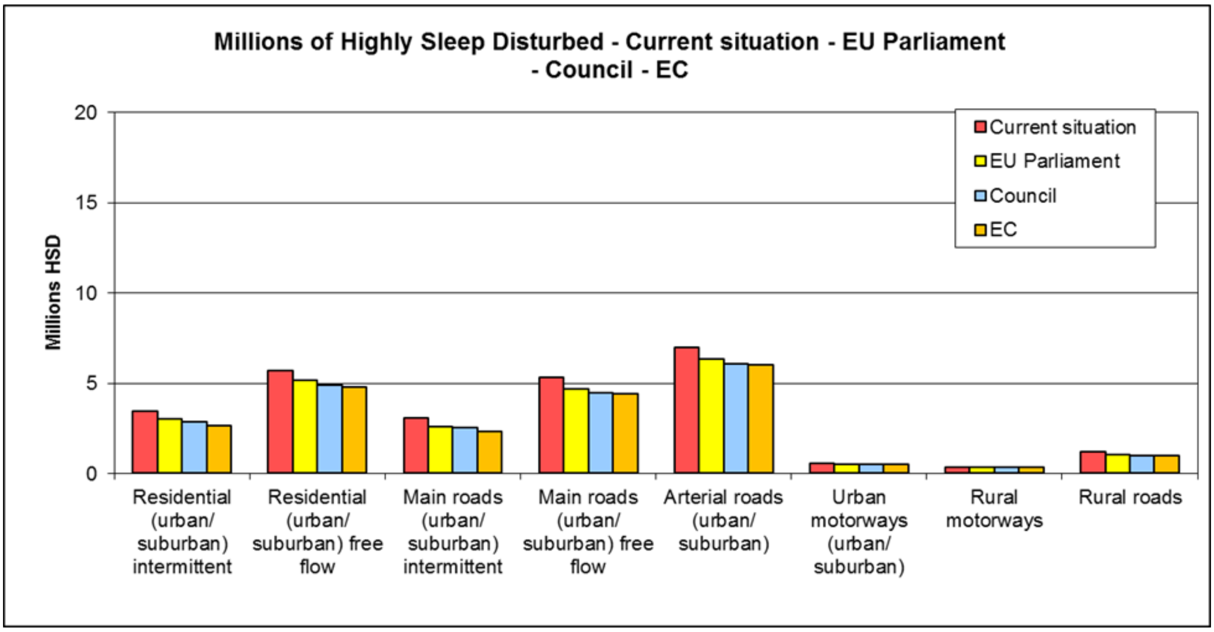

Figure A.2 – Distribution of millions of highly sleep disturbed people according to the type of road and traffic

A cost-benefit analysis was made for the impact of the proposals from the Commission (EC), the European Parliament and the European Council.

This was based on the same methodology as the VENOLIVA report [23] to which the reader is referred, with the following modifications:

- The appraisal period was 2013-2034;
- Hedonic pricing is valued at EUR 27,80 per dB per household per annum in 2013;
- Health costs are taken into account at a fixed rate of 9 Euro per dB per household per annum, based only on costs due to acute myocardial infarction (AMI);
- Noise abatement savings are based on a rate of 77,5 million Euros per dB reduction per annum, for the whole EU27;
- Industry costs include 3 years R&D and investment costs of 500 million Euro per annum from 2013-2015, in relation to the tyre Directive.

The socio-economic benefits, industry costs, benefit-to-cost ratio and net present value are set out in table A.4.

Table A.4 - Socio-economic benefits, industry costs, benefit-to-cost ratio and net present value for EP, Council and EC proposals (Amounts in millions of Euros).

Proposal	**Benefits**	**Cost Industry**	**Benefit-Cost Ratio**	**Net Present Value**
	M€	**M€**		**M€**
EU Parliament	82.900	5.996	**13,8**	76.904
Council	114.649	5.050	**22,7**	109.598
EC	144.617	6.670	**21,7**	137.947