

Regulation No. 51

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF MOTOR VEHICLES HAVING AT LEAST  
FOUR WHEELS WITH REGARD TO THEIR NOISE EMISSIONS

**Survey of Proposals for Amendments to the Regulation and Annex 3**

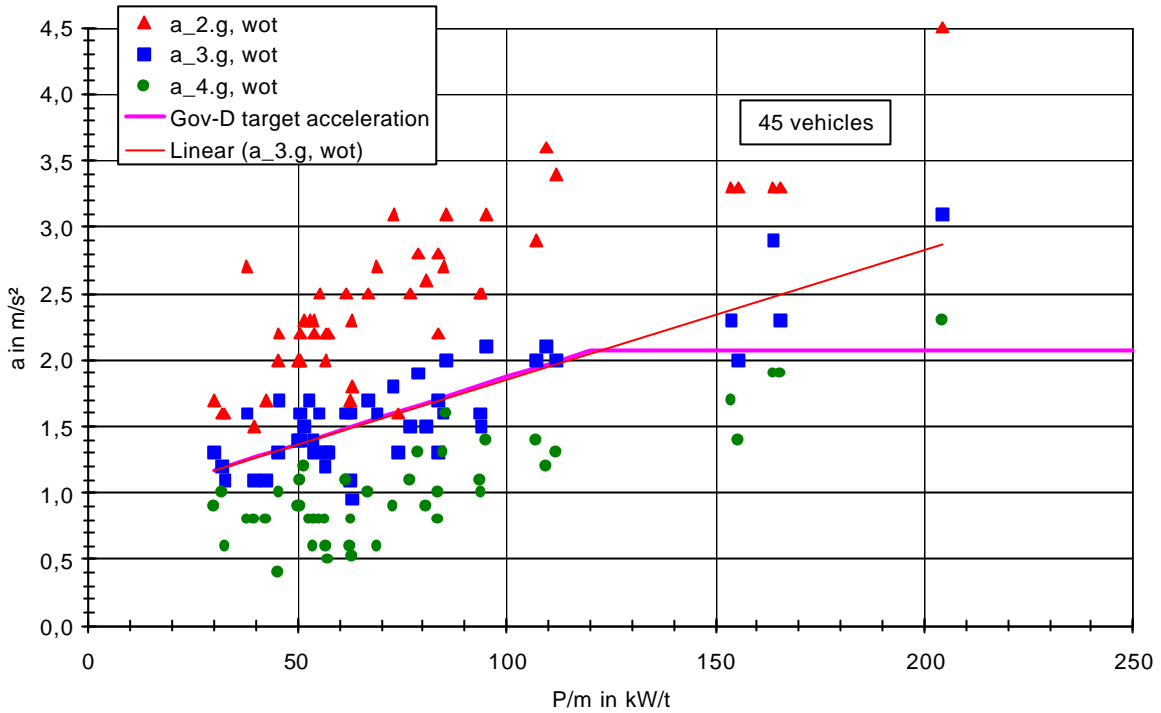
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## **Background Information**

### **1. Proposal of the German Government**

The aim of the Gov-D proposal is to bring the driving conditions for the noise test closer in line with real life operation and to make cycle bypass measures more difficult. From driving behaviour studies it is known, that the 3. gear is most frequently used for real life accelerations at 50 km/h (vehicles of today's technology) and that the acceleration values increase with increasing power to mass ratio. Wide open throttle (wot) accelerations seldom occur in urban driving. Nevertheless this principle of the existing method should be kept in order to assure a high reproducibility and to be able to test the quality of noise silencers. As a consequence, the measurement result is not fully in line with representative partial load accelerations in urban traffic.

To fulfil the above mentioned objective, the approximation function for wot acceleration in 3. gear versus power to mass ratio for state of the art vehicles was used to define the target acceleration for the noise test. To avoid extreme acceleration values that may lead to suboptimisation of tyres due to the noise increase caused by the torque effect, the target acceleration value is limited to around 2 m/s<sup>2</sup>. As the approximation function results in a value of 2,07 m/s<sup>2</sup> for a power to mass ratio of 120 kW/t, this value was finally chosen as upper limit. The wot acceleration values of a car sample representing today's technology and the approximation function for 3. gear are shown in Figure 1. The results were delivered by European vehicle manufacturers via ACEA.. The requirement that the target acceleration must be reached makes cycle bypass measures more difficult.

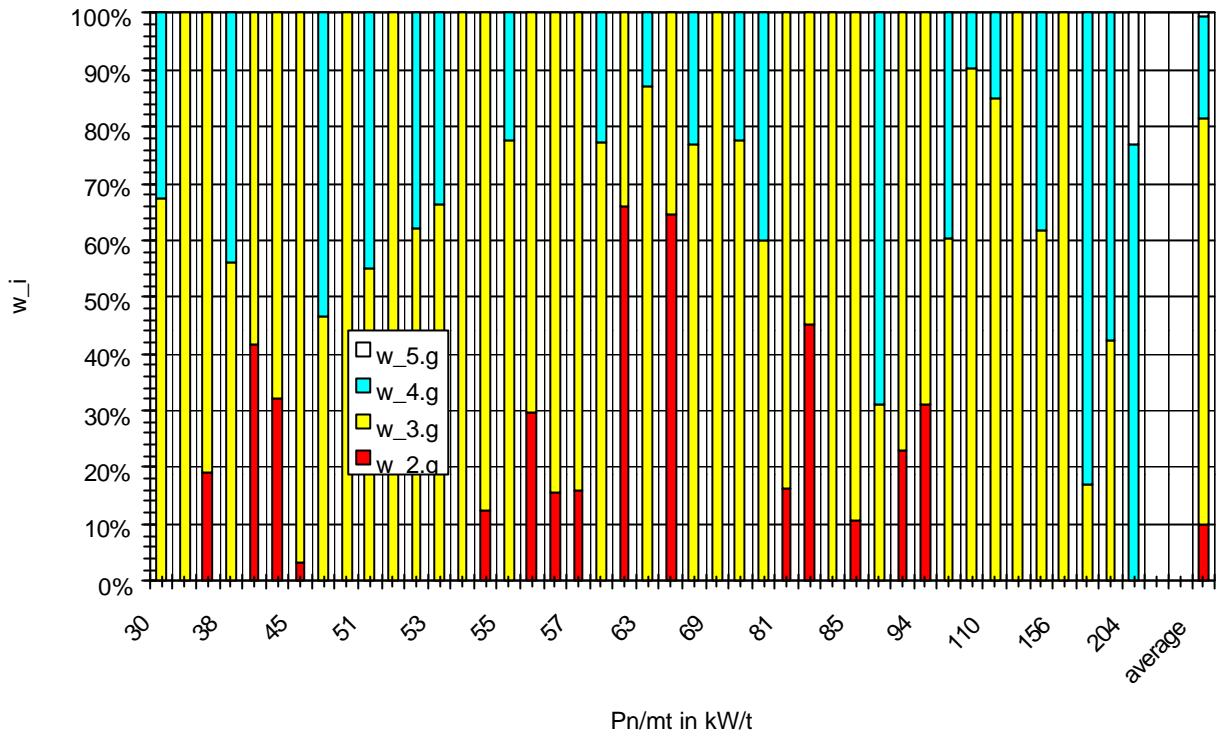


**Figure 1: Target acceleration values of the Gov-D proposal**

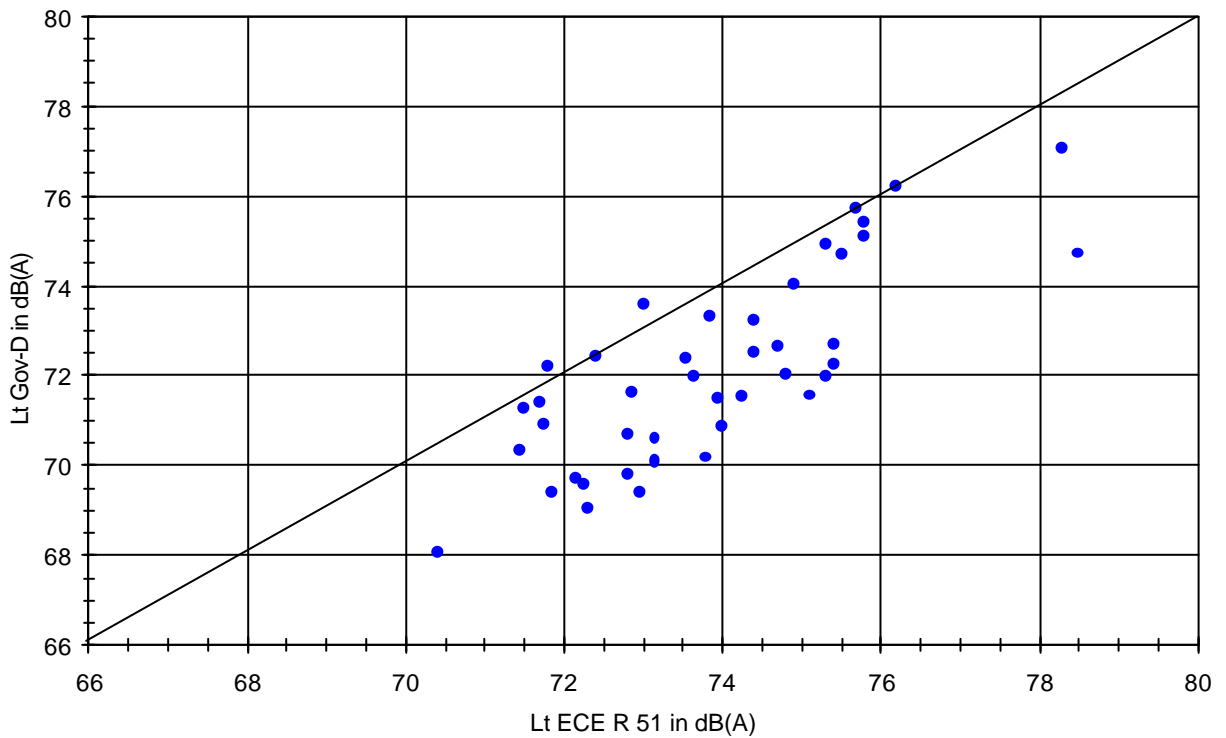
The test will be done in that gear or in that selector position of an automatic gearbox, where the target acceleration value is reached. If this condition cannot be fulfilled, two tests have to be carried out, one in a gear, where the acceleration value is higher than the target value and one, where the acceleration value is lower than the target value. The final result is the weighted average of both results. The “distances” of the acceleration values from the target value define the weightings. The power to mass ratio is the rated power divided by the kerb mass plus 75 kg.

Figure 2 shows the weightings of different gears for the above mentioned car sample. It can clearly be seen that the correlation between power to mass ratio and tested gears is rather poor. 35% of the cars will be tested in 2. and 3. gear, in most of these cases with a higher weighting for the 3. gear. 63% of the cars will be tested in 3. and 4. gear, in most of these cases with a higher weighting for the 3. gear. The car with an extreme high power to mass ratio will be tested in 4. and 5. gear. If this proposal would come into force, it can be foreseen, that the manufacturers will change the characteristics of their vehicles in a way, that testing in 2. gear will be an exception.

Figure 3 shows a comparison of test results for ECE R 51 and the Gov-D proposal without any rounding and reduction for measurement uncertainties. Besides two exceptions the Gov-D proposal results are equal or lower (up to 3,6 dB(A)) than the ECE R 51 test results. The average difference is 1,8 dB(A). It is expected to go to 2,5 dB(A) with changed vehicle characteristics. The exceptions are vehicles with extreme low acceleration values in 3. gear, so that the weightings for the 2. gear is higher than 50%. It has to be pointed out however, that these results are based on an entrance speed of 50 km/h and not on 50 km/h at the microphone line PP'.



**Figure 2: Weightings of different gears for the Gov-D proposal (43 cars, increasing power to mass ratio order)**

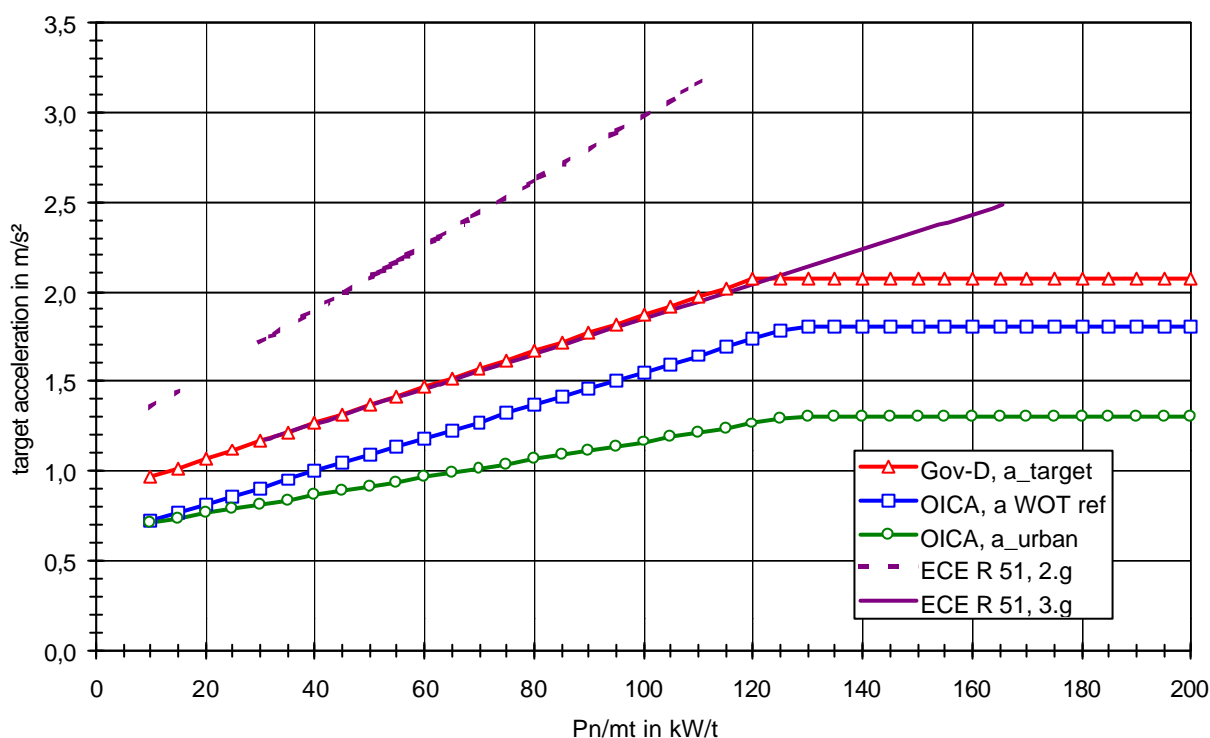


**Figure 3: Comparison of measurement results for the ECE R 51 procedure and the Gov-D proposal**

## 2. OICA Proposal

The objective of the OICA proposal is to approximate the noise emission of a typical partial load acceleration process in urban driving (most frequently used) by combining the results of the noise emission for WOT acceleration and constant speed pass-by tests. Parts of the approach are similar to the Gov-D proposal. So, there is a target function for the acceleration of the wot test in dependence of the power to mass ratio. It is shown in Figure 4, together with a target value for the acceleration typical for urban driving and the target function of the Gov-D proposal. The target value for the acceleration typical for urban driving is used to define the weighting factors for the wot acceleration and the constant speed test.

The procedure to get the test result for wot acceleration is the same as for the Gov-D proposal, but the acceleration values are 0,26 to 0,33 m/s<sup>2</sup> lower. The test will be done in that gear or in that selector position of an automatic gearbox, where the target acceleration value is reached. If this condition cannot be fulfilled, two test have to be carried out, one in a gear, where the acceleration value is higher than the target value and one, where the acceleration value is lower than the target value. The final result is the weighted average of both results. The “distances” of the acceleration values from the target value define the weightings.



**Figure 4: Target or reference values for the OICA proposal**

The constant speed tests have to be carried out in the same gears and averaged using the same weightings as for the wot tests. Figure 5 shows these weightings for a sample of 32 today’s vehicles. There is only one case where the tests have to be carried out in 2. and 3. gear. 72% of the sample would be tested in 3. and 4. gear with higher weightings for the 4. gear in most of these cases. Four vehicles would be tested in 4. gear only and five vehicles even in 4. and 5. gear. As for the Gov-D proposal there is only a poor correlation between gear choice and power to mass ratio.

The weighted averages of wot acceleration and constant speed tests are then combined to the final test result by using the following weightings:

$$L_{urban} = a_{urban}/a_{wot} * L_{wot} + (1 - a_{urban}/a_{wot}) * L_{cst}$$

The weighting for the wot acceleration test results is 90% for a power to mass ratio of 30 kW/t and goes down to 72,2% for power to mass ratios above 127 kW/t (see. Figure 6).

Figure 7 shows a comparison of test results for ECE R 51 and the OICA proposal without any rounding and reduction for measurement uncertainties. The OICA proposal results are between 1,3 and 5,4 dB(A) lower than the ECE R 51 results. The average difference is 3,6 dB(A). Figure 8 shows a comparison of test results between the Gov-D and the OICA proposal. The correlation is quite high.

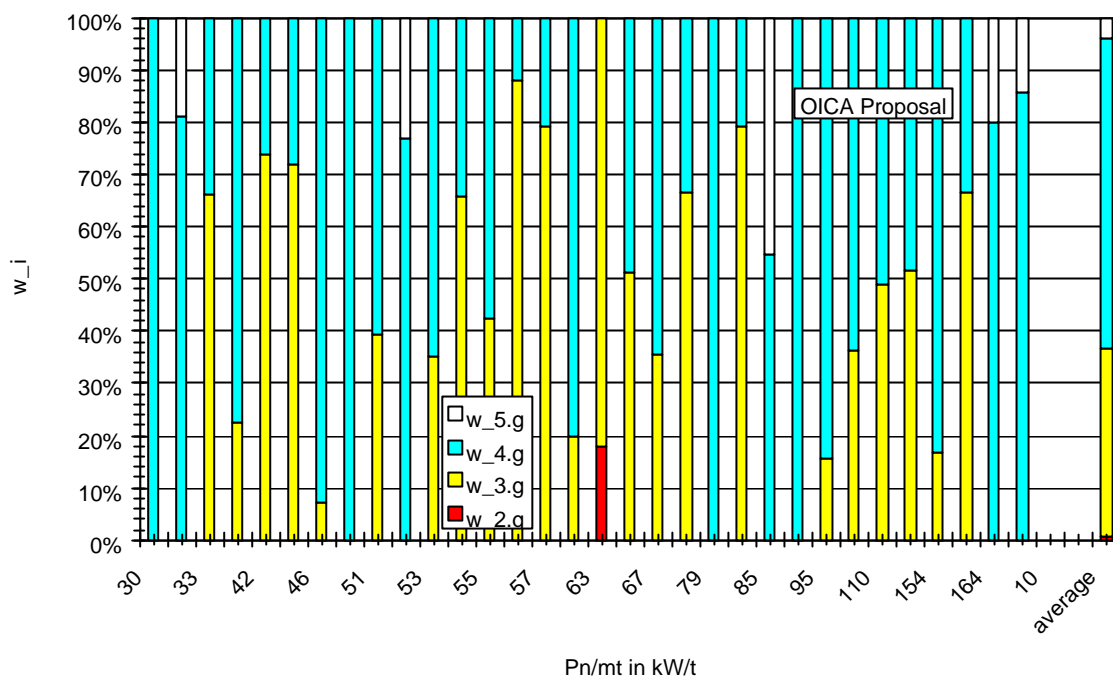


Figure 5: Weightings of different gears for the OICA proposal (32 cars, increasing power to mass ratio order)

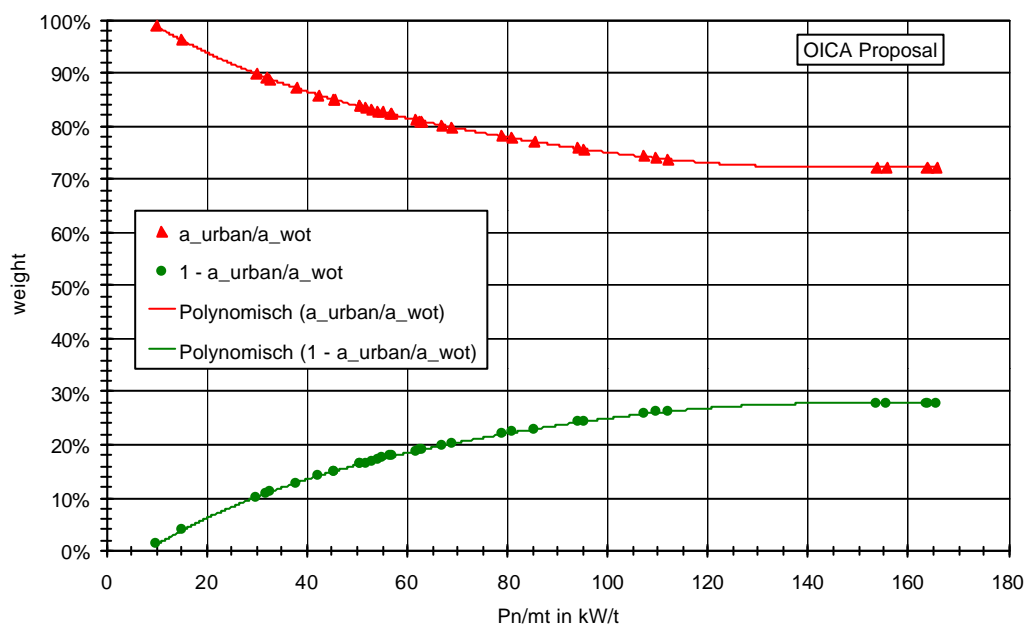
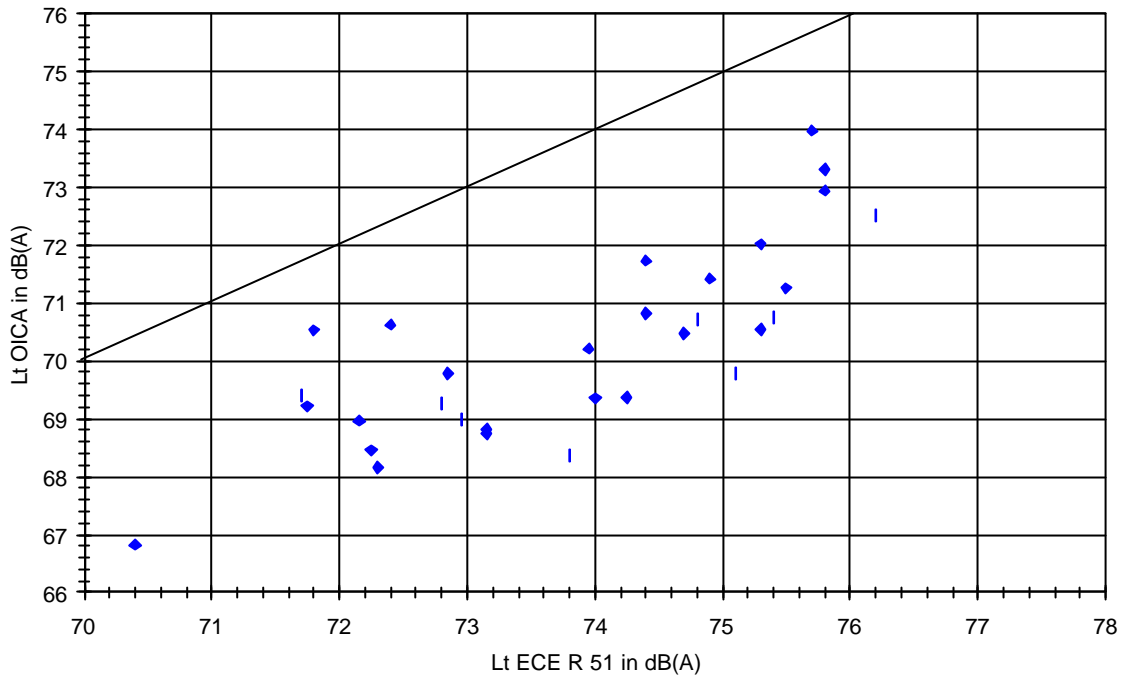
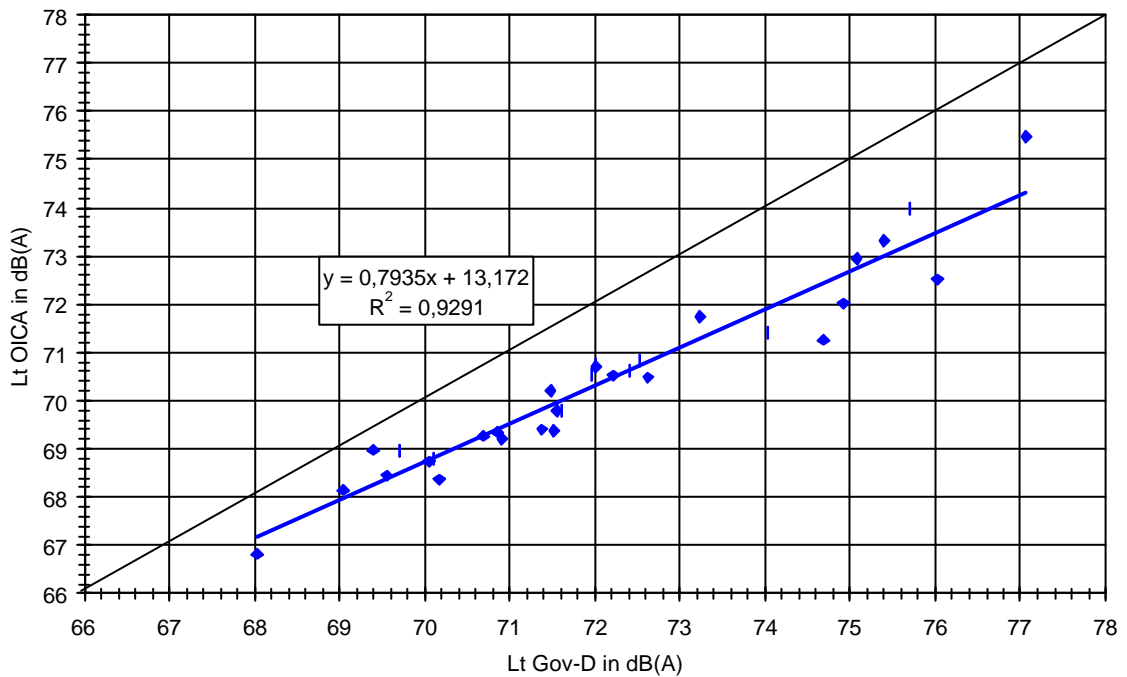


Figure 6: Weighting factors for the wot acceleration test result ( $a_{urban}/a_{wot}$ ) and the constant speed test result ( $1 - a_{urban}/a_{wot}$ ) in dependence of the power to mass ratio



**Figure 7: Comparison of measurement results for the ECE R 51 procedure and the OICA proposal**



**Figure 8: Comparison of measurement results for the Gov-D and the OICA proposal**

### 3. Proposal of the Netherlands Government

The proposal of the Netherlands government can be described as an extended OICA procedure. Two vehicle test speeds are proposed, 30 km/h and 50 km/h. At each speed wot acceleration and constant speed tests have to be carried out. The tests and the calculation method for the wot acceleration and constant speed results are identical with the OICA proposal. An analogous procedure is proposed for the tests at 30 km/h. The final test result is achieved by weighted averaging using the following weightings:

$$L_t = 0,1 * L_{wot, 30} + 0,2 * L_{cst, 30} + 0,35 * L_{wot, 50} + 0,35 * L_{cst, 50}$$

To get an impression about the outcome of this proposal compared to the others, measurement results of TÜV Automotive within a project of the German environmental agency at the following driving conditions were combined:

- Wot acceleration in 2. gear, entrance speed 20 km/h
- Constant speed test in 2. gear at 30 km/h
- Wot acceleration in 4. gear, entrance speed 50 km/h
- Constant speed test in 4. gear at 50 km/h

The required measurement results are available for 6 different cars, for another 4, results of the Gov-D and OICA proposals could be used. The results are summarised in Table 1. It should be pointed out again, that the tests for wot accelerations have been carried out with a fixed entrance speed rather than a fixed speed at the microphone line PP'. On an average the results of the Gov-D proposal are 6,2 dB(A) lower than the results of the ECE R 51 regulation.

	veh 7	veh 1	veh 2	veh 4	veh 5	veh 6	veh 11	veh 15	veh 16	veh 17		
<b>Pn in kW</b>	40	90	210	55	110	66	142	75	92	142		
<b>s in min<sup>-1</sup></b>	5300	5500	5800	5000	5700	6300	6400	3000	4200	5100		
<b>Cap. in cm<sup>3</sup></b>	1239	1799	4000	1781	1781	1396	2988	2874	2151	2435		
<b>m0 in kg</b>	810	1350	1680	1005	1355	1040	1425	1920	1410	1410		
<b>Lt<sub>yp</sub> in dB(A)</b>	73	74	70	74	71	72	69	75	71	70		
<b>Pn/mt in kW/t</b>	45,2	63,2	119,7	50,9	76,9	59,2	94,7	37,6	62,0	95,6	<b>average</b>	<b>range</b>
<b>Lt ECE R 51 in dB(A)</b>	71,3	74,1	72,1	70,6	70,0	71,9	71,1	76,4	70,1	71,5	71,9	6,3
<b>Lt Gov-D in dB(A)</b>	68,9	72,4	71,3	69,3	69,5	70,0	69,0	73,5	70,3	71,0	70,5	4,6
<b>Lt OICA in dB(A)</b>	68,1	70,4	69,2	67,8	67,8	66,7	67,3	71,3	69,3	67,9	68,6	4,6
<b>Lt Gov-NL in dB(A)</b>	65,7	67,8	67,2	65,3	64,9	63,1					65,7	4,7
<b>Lroll at 50 km/h in dB(A)</b>	65,6	68,1	65,9	64,9	65,1	62,3	64,5	68,5	67,2	65,5	65,7	6,2
<b>p_rolling ECE R 51</b>	41,4%	40,5%	41,4%	38,4%	45,5%	16,5%	41,5%	21,8%	73,0%	43,7%	40,4%	56,5%
<b>p_rolling Gov-D</b>	66,8%	55,3%	46,7%	46,2%	50,1%	24,1%	58,4%	41,1%	71,6%	47,4%	50,8%	47,5%
<b>p_rolling OICA</b>	73,0%	74,7%	61,9%	59,0%	65,0%	44,5%	73,9%	65,6%	79,4%	79,5%	67,6%	35,0%
<b>p_rolling Gov-NL</b>	61,7%	70,5%	55,9%	61,1%	68,8%	56,9%					62,5%	14,7%

**Table 1: Measurement results for ECE R 51 regulation and the different amendment proposals including an estimate for the Gov-NL proposal**

The measurements were carried out on an ISO test track. The vehicles were borrowed from car trading companies. So, the tyres were more or less random samples. The rolling noise levels at 50 km/h range from 62,3 dB(A) to 68,5 dB(A). It can be expected that the rolling noise range of tyres used for type approval testing would only be half of this range.

The rolling noise influence on the results of the wot acceleration test and the constant speed test were calculated on the basis of a regression analysis of the rolling noise levels. The result of this calculation is also shown in Table 1. The highest influence was found for the OICA proposal (67% on average), followed by the Gov-NL proposal (62% on average). In some cases the rolling noise influence for the Gov-NL proposal is even higher than for the OICA proposal, whereas the rolling noise influence of the Gov-D proposal (51% on average) is lower in all cases.

Because the differences in the rolling noise levels are not typical for type approval, an additional calculation was performed where the results were corrected to uniform rolling noise levels for all vehicles (65,1 dB(A) at 50 km/h). The results are shown in Table 2. Compared to Table 1 the range of the results for the OICA proposal is reduced by 2,7 dB(A), that of the Gov-NL proposal even by 3 dB(A), whereas the range of the Gov-D proposal is only reduced by 0,6 dB(A).

	veh 7	veh 1	veh 2	veh 4	veh 5	veh 6	veh 11	veh 15	veh 16	veh 17		
Pn in kW	40	90	210	55	110	66	142	75	92	142		
s in min <sup>-1</sup>	5300	5500	5800	5000	5700	6300	6400	3000	4200	5100		
Cap. in cm <sup>3</sup>	1239	1799	4000	1781	1781	1396	2988	2874	2151	2435		
m0 in kg	810	1350	1680	1005	1355	1040	1425	1920	1410	1410		
Ltyp in dB(A)	73	74	70	74	71	72	69	75	71	70		
Pn/mt in kW/t	45,2	63,2	119,7	50,9	76,9	59,2	94,7	37,6	62,0	95,6	average	range
Lt ECE R 51 in dB(A)	70,9	72,7	71,4	70,7	70,0	72,5	70,9	75,7	68,7	70,9	71,4	7,0
Lt Gov-D in dB(A)	68,3	70,7	70,5	69,4	69,5	70,8	68,8	72,3	68,8	70,4	70,0	4,0
Lt OICA in dB(A)	67,5	68,3	68,5	68,0	67,8	68,3	67,2	69,0	67,8	67,2	68,0	1,9
Lt Gov-NL in dB(A)	65,3	65,7	66,6	65,4	64,9	65,0					65,5	1,7
Lroll at 50 km/h in dB(A)	65,1	65,1	65,1	65,1	65,1	65,1	65,1	65,1	65,1	65,1		
p_rolling ECE R 51	37,6%	24,4%	30,6%	39,2%	45,5%	25,8%	37,7%	12,3%	62,4%	37,3%	35,3%	50,0%
p_rolling Gov-D	61,8%	37,4%	36,4%	47,1%	50,1%	36,0%	56,3%	24,4%	60,6%	41,0%	45,1%	37,4%
p_rolling OICA	69,4%	58,6%	53,7%	61,0%	65,0%	58,6%	72,8%	49,1%	71,2%	75,2%	63,5%	26,1%
p_rolling Gov-NL	63,0%	56,7%	46,9%	60,9%	68,8%	67,3%					60,6%	22,0%

Table 2: Results of Table 1 but corrected to uniform rolling noise levels for all vehicles

## 1. Engine Speeds related to the WOT Acceleration Test Results

Finally some information shall be delivered on the engine speeds that are related to the wot acceleration test results. These values are shown in Figure 9 to Figure 11 for the 3 proposals and the ECE R 51 regulation. All proposals lead to lower speeds, especially for vehicles with high power to mass ratios. In some cases the engine speed does not exceed 33% of rated speed which corresponds to 1800 min<sup>-1</sup> for a rated speed of 5500 min<sup>-1</sup>.

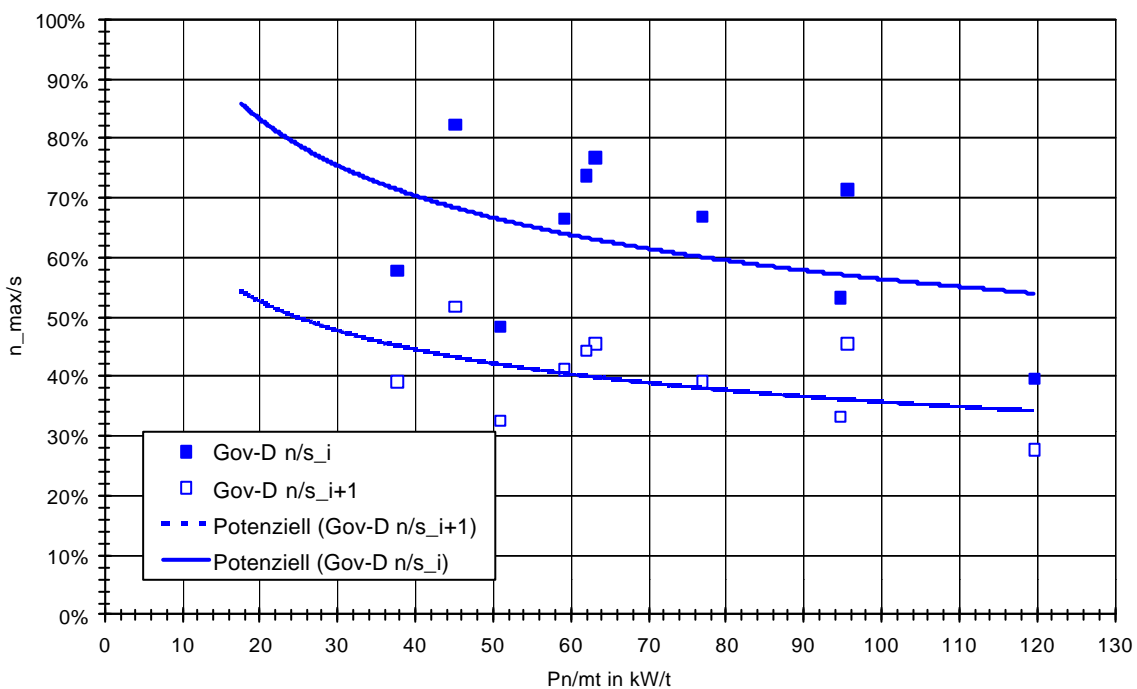
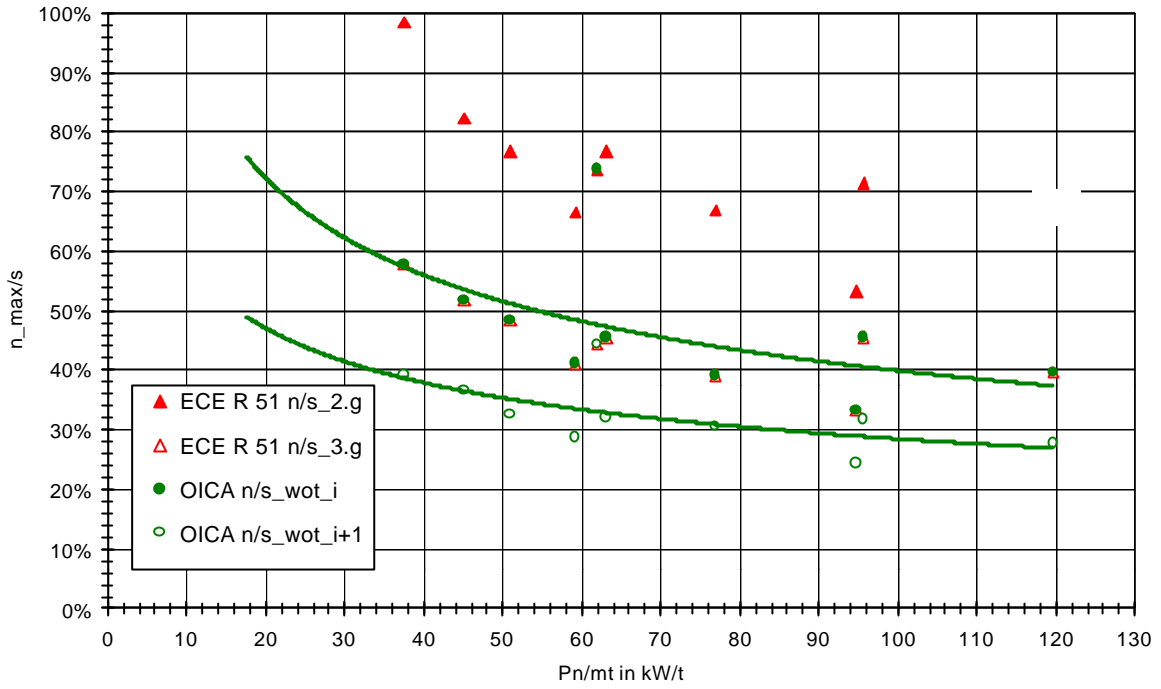
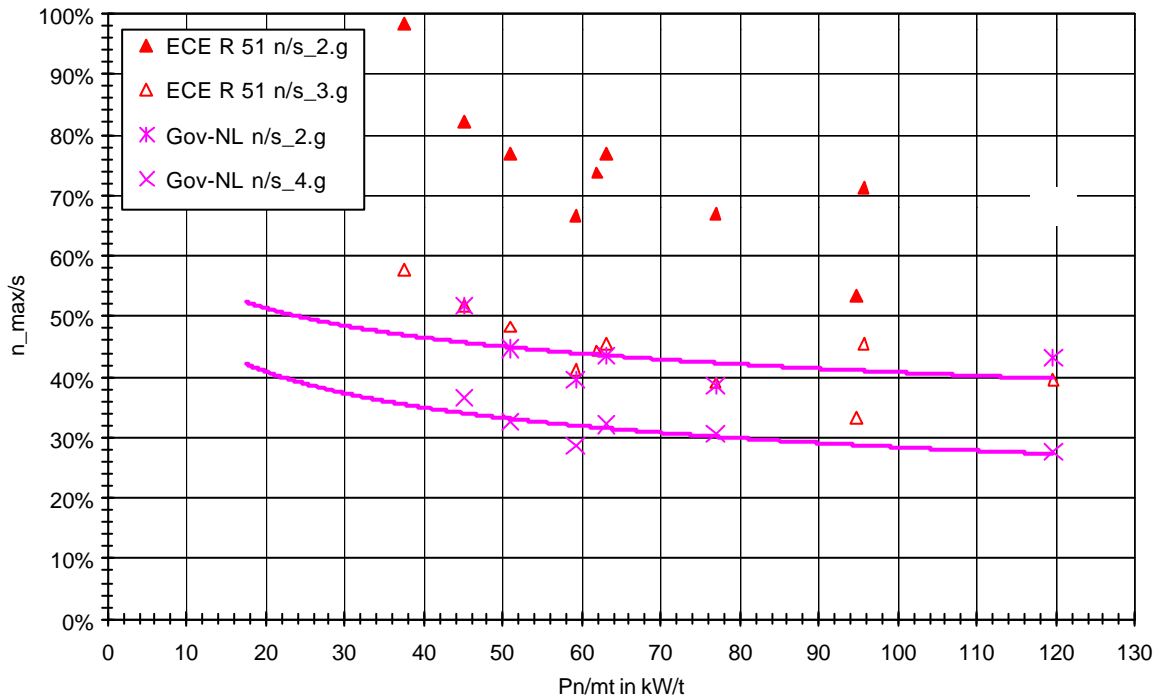


Figure 9: Normalised engine speeds at L<sub>max</sub> for the measurement conditions of the Gov-D proposal



**Figure 10: Normalised engine speeds at  $L_{max}$  for the measurement conditions of the OICA proposal**



**Figure 11: Normalised engine speeds at  $L_{max}$  for the measurement conditions of the Gov-NL proposal**