Developments in Regulations for Sound Emission of L-category vehicles

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Summary
L-category vehicles include mopeds, scooters, motorcycles, trikes, quads and minicars in the UNECE and EU Regulations which cover sound emission. These vehicles are an important source of environmental noise, are growing in number, and are not properly reflected in noise mapping. Noise disturbance due to high peak noise levels caused by these vehicles is common along popular motorcycle touring routes, especially during good weather, but occurs also in urban areas. Reasons for high noise levels in practice include illegal exhausts, technical manipulation, excessive driving behaviour, lack of enforcement and a type approval test method in need of improvement. Local enforcement is essential to reduce disturbance, but the UNECE and EU Regulations also play an important role, covering sound limits, the test method for type approval of new vehicle types and provisions to avoid circumvention and to regulate market surveillance. Two studies were performed for the European Commission in recent years to evaluate potential improvements to the regulations in relation to the type approval test method and sound emission limits. The main findings and recommendations are presented in this paper.

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1. Introduction

Sound emission testing for type approval and limits of mopeds, scooters, motorcycles, trikes, quads and minicars are covered in the UNECE and EU Regulations. These L-category vehicles have long been a significant environmental noise source and their number in the EU28 is around 36 million. The increasing public awareness and complaints for the noise from these vehicles has led to the call for improved legislation to reduce environmental noise. Reasons for high noise levels in practice include illegal exhausts, technical manipulation, excessive driving behaviour, lack of enforcement and a type approval test method needing improvement to avoid loopholes for circumvention.

There are two main paths to address these issues: firstly, enforcement of legislation at local and national level, and secondly, the improvement of legislation at international level for test methods, conformity rules and appropriate sound limits.

Two studies were performed for the European Commission (EC) to evaluate potential improvements to the regulations in relation to the test method and sound limits. The main findings and recommendations from both studies are presented in this paper.

2. Environmental noise from L-category vehicles

L-category vehicles are a special case in terms of environmental noise due to the large variation in sound levels in practice. Noise disturbance from these vehicles with high peak noise levels is common to a high extent along popular motorcycle touring routes, but also occurs in urban areas. Mopeds mainly cause disturbance in urban and residential areas.
Peak sound levels can easily exceed that of cars by 10 dB and sometimes even 20 dB or more. Illegal exhausts and reckless driving (speeding, high acceleration and engine revving) are well known causes for this. It is relatively simple to replace an exhaust on a motorcycle or to increase the maximum engine speed for mopeds; replacement parts are readily available via Internet and often cheaper than original parts.
Driving behavior and illegal exhausts can be addressed by sufficient roadside enforcement by police and, to a certain extent, by compulsory training. However, 'road legal' vehicles can still produce sound levels well above that of trucks, due to relatively high sound limits and shortcomings of the type approval test method, which does not sufficiently reflect the real driving cycle and leaves room for circumvention. The latter occurs by means of exhaust flaps or valves that react to the driving conditions, or by electronic means, known as cycle beating or defeat devices. This means that the sound produced outside of the strict test conditions ('off-cycle') can be much higher than the test result.

3. Two studies on Regulations

3.1 UNECE and EU Regulations

The sound of L-vehicles is covered in regulations listed in Table I. The UNECE Regulations specify the test method for pass-by sound level determination, the sound emission limits and rules for conformity such as marking and documentation within the homologation procedure of new vehicle types. The EU Regulation refers to UNECE ones and covers in addition market surveillance aspects. The development of the UNECE Regulations is done by the GRB, a working party of the UNECE World Forum for the harmonization of vehicle regulations (WP.29) in Geneva.
The type approval test method to assess limit compliance in the UNECE Regulations is a pass-by test for L_{pAFmax} at acceleration from 35 to 50 km/h with wide open throttle (WOT) and maximum engine load resulting in L_{WOT}, and for motorcycles combined with a constant speed test resulting in L_{crs}, (same as cars).

Table I. Applicable UNECE and EU Regulations for sound emission of L-vehicles and replacement exhausts.

Regulation	***L-category***
UNECE Regulation No. 63: Sound emission of mopeds	L1
UNECE Regulation No. 41: Sound emission of motorcycles	L3
UNECE Regulation No. 9: Sound emission of three- and four-wheel vehicles	L2, L4, L5, L6, L7
UNECE Regulation No. 92: Replacement exhaust systems	L1, L2, L3, L4, L5
Regulation (EU) No 168/2013 (and 134/2014 Approval and market surveillance of two- or three-wheel vehicles and quadricycles	L1, L2, L3, L4, L5, L6, L7

The resulting quantity is L_{urban}, a calculated mix of L_{WOT} and L_{crs} and, therefore, always lower than the L_{WOT} level. A stationary test is also defined for the sound level close to the exhaust, measured during an engine speed deceleration starting from a fixed engine speed and ending at idling speed, which can be used for in use compliance testing and enforcement. A label with the reference sound level and engine speed measured during type approval is attached to the vehicle. A so-called e-label is also required for marking replacement exhausts as being compliant with the type approval requirements.
The Regulation (EU) No 168/2013 is comparable to Regulation (EU) No 540/2014 for sound limits of road vehicles.

3.2 The studies

The two studies comprised the following:

- enhanced sound emission requirements for mopeds, quads and replacement silencers of L-category vehicles (2016). This was a due diligence study on UN Regulations Nos 9, 63 and 92 before considering their accession into the EU regulatory framework.
- Euro 5 sound emission limits of L-category vehicles (2017). This study was an assessment

of potential changes to the sound limits of all L-category vehicles, for possible introduction from around 2020.

Both studies were performed for EC DG GROW by EMISIA, LAT, HSDAC and TNO, the second study also with Ricardo. In both studies a similar approach was taken: a stakeholder consultation on the issues concerned, analysis of the results and required changes to the regulations, a cost-benefit analysis, and, finally, recommendations on sound emission limits and the test methods. In the sound emission limit study, also several vehicles were tested to evaluate compliance.

4. Consultations with stakeholders

In order to collect the views of the main stakeholders concerned with L-vehicles sound emissions and noise production in general, a questionnaire was compiled and sent out to 140 entities, including:

- Industry: manufacturers and their associations, suppliers and distributors;
- Governmental and regulatory authorities: ministries, local authorities, municipalities, technical services and type approval authorities, departments of transport, market surveillance and enforcement authorities;
- Social partners: European networks, citizens and interest groups; motorcyclist associations, environmental organizations and institutes, and noise abatement societies.

The aim was to gather responses from stakeholders with particular technical expertise on sound emissions and limits, technological solutions, and the test procedure. Responses from social partners dealt with issues such as the environmental and health benefits of noise reduction.

There were 114 replies in total, of which 81 completed questionnaires received (from both studies). This number of responses and the qualitative assessment of the replies ensured their representativeness, the validity of their technical content, and the adequate feedback gathering from a wide range of interested stakeholders.

The main findings from the analysis of the responses, are summarized as follows:

- Noise nuisance perceived from L-vehicles is still considered to be a significant problem for many European cities. The problem is more intense in urban and rural areas (compared to motorways which are considered as less affected) and most of the perceived noise is considered to come from tampered vehicles.

<u>Sound limits</u>

- Technical knowledge is available and existing technology is mature enough, so that current (Euro 4) limits are quite easy to meet for most of the L-categories. These limits are in effect based on those applicable since the 1990s (Directive 97/24/EC chapter 9), remaining unchanged for almost 20 years.
- Almost 94% of social partners, especially non-bikers and environmental organizations, want to see a significant decrease in sound emission limits. However, by carefully reading the answers provided, this high percentage (94%) is interpreted as a general requirement to reduce the excessive sound emissions (noise) produced by the inappropriate usage of vehicles and rider behaviour.
- The industrial stakeholders have significant concerns about lowering the sound emission limits, as this measure alone is not considered sufficient, if not combined with better enforcement and measures against illegal aftermarket exhausts and anti-tampering. Furthermore, it entails the risk to drive even more customers to purchase illegal aftermarket systems in order to increase the sound in practice.
- National authorities express an intermediate position (in between social partners and industry), suggesting a moderate reduction in sound emission limits depending on the vehicle category or subcategory. This reduction should be combined with specific technical improvements in the test procedure.
- Regarding the range of limits that could potentially be achieved at the Euro 5 step, the responses from social partners and national authorities converge to the conclusion that a 2-3 dB(A) reduction can be achieved in a period of 3-5 years (for industry adaptation to lower limits). However, the manufacturers are of the opinion that more like 5-6 years for a 1-2 dB(A) reduction is required, due to technical difficulties and additional technology requirements.
- Specific technical measures in order to achieve lower sound emission limits include: larger silencers, better shielding and covering, modifications of the inlet and exhaust systems, better engine design and optimization for noise and vibration, optimization of the combustion process and specific ECU software.

Additional measures

- Reducing the noise from L-category vehicles does not only depend on lowering the type approval sound emission limits. Any proposal for lower limits should be combined with a package of additional measures in order to further increase significantly the environmental and health benefits from lower noise levels.
- These measures are related to better enforcement, closing loopholes and grey areas in regulation, and dealing with illegal exhausts (anti-tampering issues). Specific technical improvements in the test procedure (both for the main test and additional sound emission provisions - ASEP) are also required, so that the test can be considered as more representative of real world driving conditions (rider behaviour and realistic full throttle acceleration test).
- From these measures, the improvements in the test procedure and additional sound emission provisions can be addressed by the type approval legislation, whilst better enforcement and in-use conformity checks are mainly a Member State responsibility. Driving behaviour is a matter of educating riders in environmental protection, whilst illegal exhausts and anti-tampering measures should be tackled with the collaboration of legislators, manufacturers, enforcement authorities and drivers.

5. Improvements in Regulations

5.1 Mopeds, quads, and replacement exhaust silencers

Two types of amendments to the UN Regulations Nos 9, 63 and 92 were put forward, all of which were adopted in the 64th meeting of GRB:

- Editorial changes in order to bring these regulations on par with UN Regulation 41-04 and Regulation 51-03, where appropriate, and to make several paragraphs clearer and better structured.
- Substantive technical amendments aiming to better cover the specifications of the vehicles or to introduce additional control of sound emissions.

Key points included the following, some of which were applicable to more than one regulation:

- Definition of the type of vehicles covered.
- Inclusion of hybrid vehicles.
- Consistent use of some symbols such as rated engine speed n_{rated}, rated maximum engine power and maximum vehicle speed v_{max}.
- Use of reference mass instead of kerb mass.
- Reference to the latest version of the applicable ISO standards.

For UN Regulations 9 and 63 a new paragraph 4 was inserted specifying the necessary data to be reported in order to facilitate in motion testing of the vehicle in use: *"With regard to in use compliance tests it is well known from former research studies that stationary tests are not very effective, because there is not enough load on the engine and silencers can be constructed such as to comply with stationary tests but lead to excessive sound emissions for full load acceleration tests. It is therefore proposed to provide the data which is necessary to perform in use compliance tests according to Annex 3, paragraph 3.1. This item is already implemented in Regulation No. 41-04."*

In order to prevent loopholes in the sound emission requirements, the following text was suggested in UN Regulation 9 Paragraph 6.2.1.1: *"If the vehicle has user selectable software programs or modes which affect the sound emission of the vehicle, all these modes shall be in compliance with the requirements in this paragraph. Testing shall be based on the worst case scenario."*

UN Regulation 92 now refers to "Non-Original Replacement Exhaust Silencer Systems" (NORESS) instead of RESS. A new paragraph 6.3 "Additional requirements" covering "Tampering protection provisions", "Multi-mode NORESS" and "Prohibition of defeat devices" was added in order to ensure the same level of stringency for a NORESS compared to UN Regulations 9 and 63. Furthermore, a sub-paragraph 6.3.4 "Additional sound emission provisions" was added for NORESS intended for the use on vehicles that are type approved according to UN Regulation No. 41-04 and are subject to the ASEP requirements, in order to ensure the same level of stringency for a NORESS. In addition, ASEP comparable to those already implemented in UN Regulation No. 41-04 were proposed for UN Regulation No. 9. Many other minor improvements were also proposed.

The effect in practice of all these amendments should be to reduce excessive noise levels in the future for mopeds, tricycles and quads, but also for motorcycles with replacement silencers. Enforcement will remain a necessity in any case. Nevertheless, there is still room for further improvements. As already mentioned, roadside stationary tests may only be partially effective, because silencers can be tuned to perform well at

stationary conditions but allow high sound levels when used in acceleration mode. Although specifying a roadside or inspection and maintenance test including vehicle acceleration is technically demanding, this is an area that could potentially lead to large improvements. Furthermore, improved vehicle allocation to UN Regulations may still be relevant, and improved ASEP for high powered L5 and L6 vehicles.
Remaining loopholes for a 'defeat device' approach may still need to be closed. For example, the strict control of entry speed for the pass-by test may give room for sound emission optimisation at acceleration from this speed only; also, the ASEP requirements in UN Regulation No. 41-04 should be reassessed with respect to the coverage of in-use driving conditions.

5.2 Potential new sound limits

The main objective of the sound emission limit study was to explore and propose new limits at a Euro 5 step of L-category vehicles, taking into account the evolution of sound levels of approved vehicle types, citizens' needs, and the technical and economic feasibility in the medium term. The current sound level limits are set out in table III (left).
The evolution of sound levels of approved vehicle types was examined with available type test data, and with new tests on selected vehicles. Source ranking was also performed on several vehicles to identify and rank the main sources and potential sound reduction measures. On most tested vehicles, the exhaust system was dominant by almost 2-3 dB(A) for the acceleration test. For some scooters, the exhaust sound level was comparable to the driveline sound level.
Motorcycles are the most critical category due to the large size of the vehicle fleet (almost 61% of total L-vehicle stock and 70% market share/sales in 2016) and high sound emission potential. In general, a 2 dB(A) sound emission limit reduction appears to be technically feasible, acceptable by the majority of stakeholders (see [8]), and leads to more benefits than costs over period 2020-2040. Even a 3 dB(A) reduction may be feasible depending on the performance impacts and additional costs; in this case, other vehicle components, apart from the exhaust, need to be tackled (intake, engine, driveline).
For higher reductions, e.g. 5 dB(A), robust conclusions could not be reached due to higher uncertainties, increased costs for the industry and technical difficulties for implementation; furthermore, such a reduction could potentially have an impact on sales which is difficult to predict.
Technical solutions include, amongst others:
- Improved design of the exhaust orifice (on all types of applications);
- Intake orifice contribution reduction by improved design, softer materials;
- Reduction of acoustic contribution of continuously variable transmission (CVT) by addition of acoustic covers (or improved design) for scooter applications;
- Engine sound emission reduction by improved design (structural attenuation) or by improved combustion control on injection applications.

For mopeds, a 1 dB(A) limit reduction can be recommended as being technically feasible and acceptable (at both technical and financial level) by the majority of stakeholders. Current limits are already significantly lower than for other L-category vehicles.

6. Cost Benefit Analysis

6.1 CBA approach in both studies

In both studies, a cost benefit analysis (CBA) was performed to justify the need for further action on regulation of sound emission of L-category vehicles. The benefits were derived from effective noise level (L_{DEN}) reductions at dwelling façades along affected roads, due to potential changes in regulation. Annoyance is generally associated with the annual average L_{DEN} level at the dwelling façade (equivalent sound pressure level weighted for day-evening-night), whereas sleep disturbance is associated with the night level L_{night}. Reducing traffic noise is considered an 'amenity' for which households are willing to pay and is reflected in the housing market. It also produces health benefits, particularly reducing the occurrence of acute myocardial infarction.
These level reductions in L_{DEN}, which are similar to those in L_{night}, were monetised with benefit valuation figures for 2020 of € 29.90/ dB/household/year for amenity and € 17.60 / dB/household/year for health (associated with heart disease only).
The cost impact associated with regulation changes were estimated for vehicle manufacturers due to additional production, R&D and testing costs, and for authorities, additional enforcement costs

(roadside checks and market surveillance). For replacement exhausts, also a potential loss was included due to reduced sales of illegal exhausts.
Benefits and costs were accumulated over a 20-year period with a 1% inflation rate and 4% discount rate (both diminished over time). The benefit to cost ratio (B/C) is the ratio between these accumulated benefits and costs over this period. The noise reduction in façade noise levels only takes effect gradually as the reduction grows due to numbers of vehicles complying with new regulation.
Only mopeds (L1) and motorcycles (L3) were considered in the analysis due to their predominant numbers within the EU Member States. Separate calculations were performed for Southern and Northern Europe, due to the difference in traffic flows of L-category vehicles versus others in these regions. In Southern Europe the traffic flow of scooters and motorcycles can be up to 20% of the total, in Northern Europe from 0.5 - 5%.
Façade noise levels (L_{DEN}) were calculated for part of the EU28 road network of 5 million km, only for inhabited sections of these and 50% of them with regular L-category vehicle traffic (1.4 million km). This included residential, main, arterial and rural roads, and motorways (included only in the first study but representing only a small portion of the total EU road network length). Numbers of exposed people could be estimated with population densities and these road lengths, at around 140m people in Northern Europe (62% of road length) and 86m people in Southern Europe (38% of road length).
For Northern Europe, only 20% of the time is taken into account for motorcycles, as these are deemed to cause the most noise exposure from L-category vehicles on days in the touring season of motorcycles and in holiday periods with good weather. For Southern Europe, mainly the Mediterranean countries, the environmental impact is considered throughout the whole year.
In the study on sound limits, only road portions with accelerating traffic were included, being one third of the above mentioned road lengths, for residential, main and rural roads. This resulted in a total exposed road length of 476,000 km, and 46 million people exposed in Northern EU and 28 million people in Southern EU.
The façade noise levels were calculated with the CNOSSOS traffic noise model at 15 m distance for residential and main roads, and at 50 m distance for rural roads. Characteristic traffic flow rates were chosen with 1 motorcycle and 1 moped to each 100 cars for the Northern EU, and 5 motorcycles and 20 mopeds to each 100 cars in the Southern EU.
The sound source levels were based on those of the traffic noise models, increased by the effect of illegal exhausts for part of the fleet or by the known increase for real driving conditions compared to the type test: 5 dB for motorcycles, 3 dB for mopeds.

6.2 CBA for study on enhanced regulations and replacement silencers

The CBA included the effect of 'illegal exhausts' under the assumption that these exceed other traffic noise levels by 10-15 dB for motorcycles and 7-10 dB for mopeds. The percentage of vehicles with such exhausts was assumed around 25%, although this may vary considerably in different countries. The scenarios calculated and their resulting benefit to cost ratios are set out in Table II. The high B/C ratios show that there can be significant benefits by reducing sound levels of L-category vehicles.

Table II: CBA scenarios and B/C ratios for enhanced regulations and replacement silencers.

Scenario	*B/C*
1. Baseline: No effect on excessive noise, no changes in enforcement or parts sales, 25% of L-category vehicles are assumed to produce more noise due to illegal exhausts.	
2. Half of all excessively noisy L-category vehicles (12.5% of total fleet) are assumed quieter, both with better enforcement and less sales of illegal exhausts.	
2a) by 15 dB for motorcycles and 10 dB for mopeds	20
2b) by 10 dB for motorcycles and 7 dB for mopeds	10
3. All excessively noisy L-category vehicles (25% of total fleet) are assumed quieter, both with better enforcement and less sales of illegal exhausts.	
3a) by 15 dB for motorcycles and 10 dB for mopeds	47
3b) by 10 dB for motorcycles and 7 dB for mopeds	21

For scenario 3b, the average reductions of equivalent noise levels for all affected roads were estimated at 0.1 dB for Northern Europe and at 1.1 dB for Southern Europe. Although these may seem small differences, sound emission, annoyance and sleep disturbance would be reduced and thereby health benefits increased significantly, in particular due to lower peak sound levels of L-category vehicles.

6.3 CBA for sound emission limit study

In the sound emission limit study, a CBA was performed to assess the feasibility of limit reductions for L-category vehicles. This was based on the potential reductions of L_{DEN} average noise levels at dwelling façades only along roads with accelerating vehicles.

During the appraisal period 2020-2040 the sound emission limits of other road vehicles (apart from L-category) are expected to be tightened by 3-4 dB following EU Regulation 540/2014. 15 scenarios were evaluated in total, including moderate (2 dB) and ambitious (5 dB) limit reduction scenarios, baseline and high market growth sub-scenarios, with or without reduction of illegal exhausts from 25% to 0%, and with or without the reduced sound levels of other traffic.

Limit changes resulted in reductions in L_{DEN} levels and B/C ratios as set out in Table III. If sound level limit reductions of other road vehicles are included (column All), L_{DEN} reductions and B/C ratios are larger. Also, reducing the percentage of illegal exhausts from 25% to 0% and off-cycle sound emissions down to the limit level, increases L_{DEN} reductions and B/C ratios.

The B/C ratio was shown to be close to 2 for most scenarios if limit reductions of other vehicles are not included. The moderate 2 dB limit reduction scenario with baseline market growth and 25% illegal exhausts results in a B/C ratio of 2.18. Baseline and high market growth show little difference because both the benefits and the costs increase with market growth.

In general, the CBA results are sensitive to the potential real world reductions in vehicle sound levels, valuation figures and industry costs. However, the underlying assumptions for input data are conservative, considering the available source data, the focus only on accelerating traffic, the effective L-category contribution in the future L_{DEN} levels, and industry costs chosen higher than for those with large production volumes.

6.4 CBA for sound emission limits based on single event analysis

As it is well known that peak sound levels or single events are relevant for motorcycle and moped noise, but not standard for traffic noise assessment, a new approach for average level reduction and CBA was proposed and tested, with the following 3 steps:

1. Estimate the total number of single events due to motorcycles and mopeds;
2. Estimate the effect of limit change on the maximum sound pressure level L_{pAFmax} of the single events;
3. Apply a valuation of € 0.001/dB/household/event and calculate the benefits for all events; costs and the further CBA are analogous to the L_{DEN} analysis.

This analysis indicated larger benefit to cost ratios of 3 to 6 for limit reductions of 2 or 5 dB, with 25% illegal exhausts, and 30-38 for limit reductions with 0% illegal exhausts.

If, for example, 10 events a day/household for a whole year are assumed above other vehicle sound levels, the suggested value would result in € 3.65 /dB/household/year. This is much lower than the amenity and health valuation figures of € 29.90 and € 17.60 /dB/household/year used for the L_{DEN}

Table III: Left, current sound limits for L-category vehicles; Right: CBA Scenarios and B/C ratios for modified sound limits, including effect of percentage illegal exhausts, growth (Business as usual BAU or High growth HGR), and with and without limit changes of other vehicles (All).

					Northern EU		*Southern EU*		*B/C ratio*	
	Current limit			*Scenario*	Δ *Lden dB*	Δ *Lden dB*	Δ *Lden dB*	Δ *Lden dB*		
Category	dB(A)			*Year/Lcatlim/%Illegal/Growth*	*All*	*Lcat*	*All*	*Lcat*	*All veh.*	*Lcat*
L1e-A	63		1	2020, 0 dB, 25% IL, REF	0	0	0	0	n.a.	n.a.
L1e-B vmax ≤ 25km/h	66		2	2020,-2 dB,25% IL, REF	0,14	0,14	0,38	0,38	2,31	2,31
L1e-B vmax > 25km/h	71		3	2020,-5 dB,25% IL, REF	0,26	0,26	0,74	0,74	1,42	1,42
L2e	76		4	2040, 0 dB, 25% IL, BAU	1,58	n.a.	1,00	n.a.	n.a.	n.a.
L3e PMR ≤ 25	**73***		5	2040, -2 dB, 25% IL, BAU	1,77	0,19	1,40	0,39	9,01	2,18
L3e 25 < PMR ≤ 50	**74***		6	2040, -5 dB, 25% IL, BAU	1,93	0,35	2,09	1,09	4,03	1,86
L3e PMR > 50	**77***		7	2040, 0 dB, 0% IL, BAU	1,91	n.a.	1,96	n.a.	11,34	n.a.
L4e	80		8	2040, -2 dB, 0% IL, BAU	2,18	0,27	2,69	0,73	7,74	1,91
L5e	80		9	2040, -5 dB, 0% IL, BAU	2,43	0,52	3,42	1,46	4,74	1,88
L6e	80		10	2040, 0 dB, 25% IL, HGR	0,73	n.a.	0,39	n.a.	n.a.	n.a.
L7e	80		11	2040, -2 dB, 25% IL, HGR	0,92	0,19	0,83	0,44	4,61	2,14
			12	2040, -5 dB, 25% IL, HGR	1,08	0,35	1,25	0,86	2,11	1,32
* Limit for Lurban			13	2040, 0 dB, 0% IL, HGR	1,06	n.a.	1,12	n.a.	6,42	n.a.
LWOT limit is around 3 dB higher			14	2040, -2 dB, 0% IL, HGR	1,33	0,27	1,84	0,72	4,89	1,78
			15	2040, -5 dB, 0% IL, HGR	1,57	0,52	2,57	1,45	3,18	1,70

analysis and is therefore probably an underestimate.

7. Conclusions

7.1 Conclusion and recommendations

The proposed amendments and improvements to UNECE regulations for mopeds, tricycles, quads and replacement exhausts should help reduce noise emission in practice due to tampering, defeat devices and illegal exhausts. Enhancement of the existing regulations for mopeds, tricycles and quads shows large benefit to cost ratios of 10-47.
Decreasing the sound emission limits of L-vehicles is necessary in general because of their high environmental impact and in order to follow the decreasing sound emission limits of other road vehicles in the future. Without limit changes in L-vehicles, the gap with other road vehicles will become even larger than it is already. The need for reduction is strongest for the loudest and most numerous vehicles, motorcycles. From an environmental viewpoint sound levels closer to those of cars would be more acceptable, as limits above 75 dB are closer to those of some truck categories.
In general, a 2 dB(A) limit reduction appears to be technically feasible for motorcycles, acceptable by the majority of stakeholders, and leads to more benefits than costs over period 2020-2040. Even a 3 dB(A) reduction may be feasible. The impact of higher reductions is harder to predict due to higher uncertainties in CBA model parameters, technical obstacles and potential impact on sales.
Accompanying measures to reduce the use of illegal exhausts, off cycle noise due to shortcomings in the test procedure, and excessive driving behaviour, will all increase the effectiveness of lower sound emission limits. Even if sound emission limit reduction is the only measure to be considered for the future, environmental and health benefits (noise reduction in real traffic and everyday life) are still significant.

7.2 Link to noise mapping

Motorcycles and mopeds are not properly reflected in noise mapping. This is in part due to the peak noise levels which do not always affect the calculated L_{DEN} levels much. But also the modelled sound source levels, such as in the EU CNOSSOS model and others, are insufficiently representative without the correction applied in these two studies, and traffic flow data for such vehicles are often lacking. This suggests a further data collection on roadside sound levels is required. Once these issues are addressed, it may be possible to make a better link with action plans.

7.3 Future outlook

Work on test methods for sound emission of L-category vehicles will continue in the GRB, for example on ASEP, the provisions for covering a wider range of realistic operating conditions.
The roadside test method has potential for further improvement, which could help in terms of enforcement. The European Commission will after due process propose new limits for L-category vehicles possibly from around 2020.

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Disclaimer
The findings and recommendations of both studies as well their presentation here do not represent the position of and do not bind the European Commission, but only reflect the position of the authors.

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