

STUDY ON EURO 5 SOUND LEVEL LIMITS OF L-CATEGORY VEHICLES PROGRESS AND CBA RESULTS

67TH GRB, Geneva



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- › Project overview,
- › Results of measurement campaign and validation tests,
- › CBA analysis, results and conclusions,
- › Consortium conclusions towards sound limit proposals.

THE PRESENTED STUDY DOES NOT BIND, IN ANY WAY,
NOR IT REPRESENTS THE EUROPEAN COMMISSION'S
VIEW.



GENERAL INFORMATION

› **Tender ID:**

- › Title: Study on Euro 5 sound level limits of L-category vehicles
- › Tender No: 524/PP/GRO/IMA/16/1131/9316
- › Contract No: SI2.736346 of the Consortium with the European Commission - DG-GROW

› **Consortium performing the work:**

- › EMISIA - Greece
- › TNO - The Netherlands
- › Ricardo Deutschland GmbH - Germany
- › Heinz Steven Data Analysis and Consultancy (HSDAC) - Germany



PROJECT OBJECTIVES

Investigate the potential for new sound limits of L-category vehicles at Euro 5 step and make a justified **proposal**, taking into account:



Citizens' needs and stakeholders interest
(**feedback gathering**)



Evolution of sound levels of road vehicles
(**actual vehicle testing**)



Technical and economic feasibility in medium term
(**cost-benefit analysis**)

- ▶ Any new sound limits to be accompanied by an appropriate **timeframe** for their introduction



TASKS

Task 1: Estimate of sound level limits for all L-categories

- a) Feedback gathering – stakeholder survey
- b) Literature review

Task 2: Verification of sound level limits

- a) Actual vehicle testing – sound measurements
- b) Processing of results

Task 3: Cost-benefit analysis

- a) Input data, scenarios, first results
- b) Improvements, final CBA results

Task 4: Validation tests

- a) Additional vehicle testing – sound measurements
- b) Noise Source Ranking (NSR)

Task 5: Proposal for limit values and reporting

Final sound limits proposed and recommendations



SUMMARY OF SURVEY AND LIT. REVIEW

› Approach:

- › Technical **questionnaire** to stakeholders (manufacturers, authorities, concerned citizens associations, environmental organizations, etc.) to collect **responses**
- › Objective to make **first proposal estimate** of new Euro 5 sound level limits

› Main outcome:

- › Potential **room for improvements** (lower sound limits) with technical measures
- › Already vehicles type-approved with **2 dB** or lower levels than limit
- › **2 dB(A)** considered moderate feasible reduction [opinions range: 0 to >5 dB(A)]



CONCLUSIONS FROM MEASUREMENTS

- › Vehicles comply with their COP criteria
- › Vehicle-specific behaviour:
 - › All three mopeds 1 dB(A) below current limit,
 - › Two of the four L3e vehicles at or close to the current TA limit,
 - › Two of the four L3e vehicles and one L5e-B vehicle 4-5 dB(A) below current TA limit,
 - › The L5e-A vehicle at the current TA limit,
 - › The L6e-BP (mini-car) 14.5 dB(A) below current TA limit
 - › The L7e-B1 (ATV) at current COP limit
- › Reduction in sound limits will have different implications for different vehicle sub-categories



VALIDATION: SOURCE RANKING CONCLUSIONS

| Category | Test Concerns | Main contributors to sound levels | Technology to achieve lower levels |
|---------------------|---------------|--|--|
| L1e-B, L2 | WOT | Exhaust main contributor, lower limit than other categories leaves less margin for reductions | Mostly exhaust but CVT as well |
| L3e, CVT | WOT, CRS | Exhaust and driveline are all important kp: power specific weighing of CRS/WOT | Exhaust sound attenuation, significant CVT attenuation necessary |
| L3e, manual | WOT, CRS | All components important CRS: intake, engine, driveline WOT: exhaust kp: power specific weighing of CRS/WOT | Vehicle specific but all four categories need to be considered. |
| L5e-A, L7e-B | WOT | No CRS contribution, hence exhaust most important | Exhaust sound attenuation Driveline in L7e-B |
| L5e-B, L6e-B, L7e-C | WOT | Vehicle specific, but definitely exhaust due to WOT test | Engine, exhaust, driveline: Better encapsulation possible |



COST-BENEFIT ANALYSIS (CBA)

- › The objective of performing CBA is to investigate the **feasibility** and **relevance** of possible new sound level limits for L-category vehicles
 - feasibility:** technical and economic
 - relevance:** effective real world noise reduction
- › The **effectiveness** of introducing improved limits depends on
 - › better **enforcement** = less excessive L-category vehicle noise due to illegal exhausts, tampering
 - › the **relation** between the limits and real world sound levels, especially the L_{WOT} levels on roads under acceleration (also: cycle bypassing for the test method)
 - › new (lower) sound limits of **other vehicles** gradually taking effect
 - › **growth** of vehicle numbers/use



BENEFITS

- › Use of L_{DEN} (average) noise levels at the dwelling facade to assess noise reductions, which can be **monetised**
- › L_{DEN} level calculated with EU traffic noise model CNOSSOS, taking **representative road** types and sections into account
- › **Valuation:**
 - › Amenity (willingness to pay): € 29.90 / dB reduction / household / annum based on EU paper 2002
 - › Health (only heart disease): € 17.60 / dB reduction / household / annum based on TNO and UK estimates used for traffic noise
- › Alternative approach would be to use assessment of **single events**, L_{Amax}



COSTS, BENEFIT TO COST RATIO

- › **Industry ADDITIONAL** costs due to additional R&D and production
(cost = price – tax – markup)
- › **Enforcement ADDITIONAL** costs for authorities and traffic police
to achieve 0% illegal exhausts in future
- › Cost approach based on **recent** "L-cat Euro 5 emission study"
 - › **Information** received from industry (3 companies, L3e, L5e)
 - › Consortium **assessment** of technological needs to achieve lower limits
- › **Benefit to cost ratio** =
$$\frac{\text{Accumulated benefits over 20 year period}}{\text{Accumulated costs over 20 year period}}$$



CBA SCENARIOS

- › **Time period: 2020 – 2040**

- › **1) Baseline scenario:** no change to L-category limits

- › **2) Reduced limits:** on average -2 dB limit reduction
Exact limit change depends on L-subcategory considered

- › **3) Ambitious scenario:** on average -5 dB limit reduction
Exact limit change depends on L-subcategory considered
Scenario aims at showing max potential benefit if other conditions are met



CONCLUSIONS, EFFECTIVENESS

- › Effectiveness of limit changes only due to L-cat limits is relatively low in terms of L_{DEN} reductions, as can be expected:
North EU: 0.1 -0.5 dB, South EU 0.4 -1.5 dB
- › Reducing the percentage of illegal exhausts and off-cycle sound production doubles the L-cat reductions in L_{DEN}
- › Much higher reductions can be expected from future steps of Regulations EU 540/2014 (M and N vehicles) and EC 661/2009 (tyres), North EU: 0.1 -2.4 dB, South EU 0.4 -3.4 dB
- › But not changing the L-cat limits on the affected roads diminishes the effectiveness of other vehicle limits
- › Benefits are much larger in South EU due to higher contribution of PTWs to overall traffic levels



CONCLUSIONS FOR B/C RATIO

- › Benefit to cost ratio is highest for scenarios with limit reductions and restriction of illegal exhausts and legal off-cycle excess noise, close to 2
- › Even if illegal exhausts remain unchanged, the B/C ratio is still above 1
- › Benefit to cost ratio is slightly higher for the moderate limit reduction, 1.92 vs 1.86 for the ambitious limit change
Reason: both costs and benefits increase
- › Costs are significantly higher for ambitious scenario (even though the B/C is similar), and more technical difficulties are expected.
- › B/C ratio similar for business as usual and high growth scenarios
- › Although LDEN reductions are small, they are significant, because underlying assumptions are conservative
- › So, a moderate limit reduction should be feasible.



FINAL CONCLUSIONS TOWARDS SOUND LEVEL LIMITS PROPOSAL

- › Based on the CBA results:
- › In general, decreasing the sound limits of L-vehicles is necessary in order to follow the decreasing regulatory trend of **other road vehicles** in the future (as already planned in Reg. (EU) No. 540/2014)
- › Without limit changes in L-vehicles, the **gap** with other road vehicles will become **even larger** than it is already; the need for limit reduction is **strongest** for the **loudest** vehicles
- › Even if sound limits 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



L3E VEHICLES (MOTORCYCLES)

- › This is the most critical category due to:
 - › i) high number of vehicle fleet compared to other categories and
 - › ii) high sound levels (potential source of noise problems)
- › In general, a 2 dB(A) limit reduction appears to be technically feasible, 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 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).



L1E-B VEHICLES (MOPEDS)

- › These vehicles have a significant market share, but with a decrease trend in recent years due to competition of larger scooters.
- › Current limits are already lower than the other L-vehicle types; hence, there is less margin for reductions.
- › Limit reduction is technically less feasible compared to L3e motorcycles due to technological and size limitations of mopeds.
- › Technology to achieve lower sound levels: mostly exhaust attenuation, but CVT as well.
- › In general, 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.



L2E VEHICLES (THREE-WHEEL MOPEDS)

- › The market size of these vehicles is very small compared to L1e-B two-wheel mopeds (almost 0.5% of all mopeds sales in 2015). They have similarities with the L1e-B vehicles regarding the engine and silencer system used.
- › Currently, there is a 5 dB(A) difference in the limit of L2e vehicles, 76 dB(A), compared to L1e-B vehicles with $v_{\max} > 25\text{km/h}$, 71 dB(A).
- › However, there is no evidence that this difference cannot be decreased, so that the limit of L2e vehicles comes closer to L1e-B vehicles with $v_{\max} > 25\text{km/h}$, leaving some margin for the three-wheel ones.
- › Hence, a limit reduction more than 1 dB(A), i.e., in the range 3-5 dB(A), can be recommended from a technical point of view.
- › A similar situation is given for **L6e-A vehicles (light on-road quads)**. In case they remain at Euro 5 step, similar powertrain to L1e-B is expected. The current limit is 80 dB(A), hence, there is high reduction potential of 5-7 dB. This is also the case for **L6e-B vehicles (mini-cars)**.



L4E (TWO-WHEEL MOTORCYCLES WITH SIDE-CAR) AND L5E (TRICYCLES) VEHICLES

- › L4e: very low number of vehicles and sales figures (almost 100 units sold per year in EU); technically similar to high performance motorcycles (L3e-A3) regarding powertrain and emissions control system.
- › L5e: these vehicles constitute a rather small market (almost 21,000 sales in 2015), but with an increasing trend over the last 5-6 years; they are distinguished into L5e-A (passenger use) and L5e-B (commercial tricycles).
- › L5e-A have technical similarities with two-wheel motorcycles (especially the L3e-A2 ones).
- › L5e-B have low number of sales (almost 2,500 vehicles in 2015) and face significant pressures over the last 5-6 years; these vehicles have more room and weight capacity for shielding and absorption.



L4E (TWO-WHEEL MOTORCYCLES WITH SIDE-CAR) AND L5E (TRICYCLES) VEHICLES

- › The current sound limit of L4e and L5e is high, 80 dB(A).
- › It is recommended to split the L4e and L5e sound level limits into PMR sub-categories similarly to L3e ones ($PMR \leq 25$, $25 < PMR \leq 50$, $PMR > 50$), so that there is some gradation in the corresponding limit values.
- › It is proposed to consider the same approach to **L7e-A vehicles (heavy on-road quads)** and **L7e-B vehicles (ATVs)** as well. Also the conclusions for limit value reductions can be adopted from L4e and L5e vehicles.
- › The differences in the measurement methods between Regulation 41-04 and Regulation 9 need to be considered.



L4E (TWO-WHEEL MOTORCYCLES WITH SIDE-CAR) AND L5E (TRICYCLES) VEHICLES

- › $PMR \leq 25$:
- › According to UN R41-04 the test for L3e vehicles with $PMR \leq 25$ W/kg is only a L_{wot} test and, thus, directly comparable with the test according to UN R9 for L4e and L5e vehicles; but the driving conditions are different.
- › The current limit value for L4e and L5e vehicles is 80 dB(A), while for the L3e vehicles with $PMR \leq 25$ W/kg it is 73 dB(A). Considering 2 dB(A) as a maximum difference related to the differences in the measurement methods, leads to an equivalent limit value of 75 dB(A) for L4e and L5e vehicles. Taking into account a 2 dB(A) limit reduction this suggests that the overall proposed limit value reduction for the L4e and L5e vehicles can be 7 dB(A).



L4E (TWO-WHEEL MOTORCYCLES WITH SIDE-CAR) AND L5E (TRICYCLES) VEHICLES

- › $25 < \text{PMR} \leq 50$:
- › The current limit value for L3e vehicles is 74 dB(A) for Lurban. According to UN R41-04, L_{wot} is limited to Lurban + 5 dB(A), which results in 79 dB(A) for the current situation. Since the specifications for the operating conditions are similarly different as for vehicles with $\text{PMR} \leq 25$ between UN R41-04 and UN R9, one has to consider a margin of up to 2 dB(A) for a comparison.
- › In this context, the current limit value of 80 dB(A) for L4e and L5e vehicles is equivalently stringent as the L_{wot} limit for L3e vehicles.
- › Consequently, a limit value reduction of the same range (2-3 dB(A)) as for L3e vehicles is also proposed for L4e and L5e vehicles.



L4E (TWO-WHEEL MOTORCYCLES WITH SIDE-CAR) AND L5E (TRICYCLES) VEHICLES

- › PMR > 50:
- › The current limit values for L3e vehicles are 77 dB(A) for L_{urban} and 82 dB(A) for L_{wot} . The operating conditions for the wide-open throttle acceleration test in UN R41-04 and UN R9 are almost the same, but in UN R41-04 the reference is line PP' while in UN R9 it is line AA'. This leads to slightly higher results for UN R9, if the same gear is used. Since in UN R9 only the 3rd gear is used (for manual transmissions with more than 4 gears), while according to UN R41-04 up to two gears could be tested and this could be 2nd and 3rd (as for the tested L3e vehicle with manual transmission within this project), the difference caused by the different reference lines could be compensated to a certain extend.
- › Similarly to vehicles with $25 < PMR \leq 50$, it can be concluded that the current limit value of 80 dB(A) in UN R9 is equivalently stringent as the current limits of UN R41-04. Consequently, a limit value reduction of 2-3 dB(A) can be also proposed for L4e and L5e vehicles in this PMR class.



L6E-B VEHICLES (MINI-CARS)

- ▶ These vehicles are similar to small M1 vehicles and are mostly used in urban environments with maximum speed 45 km/h. In the future these vehicles will be forced to turn to alternative powertrains, e.g. gasoline series hybrid or all-electric vehicles but not Diesel engines any more.
- ▶ The current sound level limit is high, 80 dB(A), although these vehicles have better encapsulation capability for non-exhaust components (e.g. engine, gearbox) compared to other L-categories.
- ▶ Furthermore, the vehicle test performed in the framework of the study and the analysis of the KBA data justify that most currently approved applications in Europe already achieve 4 to 5 dB(A) lower emission levels than the current limit.
- ▶ Therefore, it is concluded that the reduction potential is high, 5-6 dB(A), or even more so that the new limit comes closer to that of small passenger cars.



L6E-A VEHICLES (LIGHT ON-ROAD QUADS)

- › These vehicles belong to the L6e category, but they are hardly present in the EU market; for the few available, in case they remain at Euro 5 step, similar powertrain to L1e-B is expected; hence, they can be characterized as 4-wheel mopeds (UN R63 is also used for the L6e-A vehicles).
- › The current limit of these vehicles is 80 dB(A), hence, there is high reduction potential, similar to the L6e-B ones.



L7E-B VEHICLES (ATVS)

- › These all-terrain vehicles may be a potential source of noise problems, e.g. when driven in quiet rural/recreational areas and touring routes, since the current sound limit is high, 80 dB(A).
- › Similarly to the L4e and L5e ones, it is recommended to split the sound level limits into PMR sub-categories ($PMR \leq 25$, $25 < PMR \leq 50$, $PMR > 50$), so that there is some gradation in the corresponding limit values.
- › The same limit reduction ranges are proposed as for the L4e and L5e category vehicles, depending on the PMR class.



L7E-A VEHICLES (HEAVY ON-ROAD QUADS)

- › These vehicles belong to the L7e category, but there are very few models (if any) available to the market and they have marginal contribution to the L7e market size; regarding future developments, the powertrain of such vehicles is expected to be either electric or similar to L3e.
- › Similarly to the L7e-B vehicles, it is recommended to split the sound level limits into PMR sub-categories ($PMR \leq 25$, $25 < PMR \leq 50$, $PMR > 50$) and apply the same limit reduction ranges, depending on the PMR class.



TIMEFRAME FOR ADAPTATION TO NEW EURO 5 SOUND LIMITS

- › Regarding the time period required for the industry to adapt to new Euro 5 sound limits, this can vary depending on the exact limit reduction for each L-subcategory.
- › Nevertheless, an approach similar to the one already planned in Regulation (EU) No. 540/2014 for other road vehicles can be followed, i.e. distinguish between new vehicle types and all new vehicle registrations, thus, taking into account the development time of new models.
- › In general, for a limit reduction of 2 dB(A), a 2-3 years period is considered sufficient for new vehicle types, plus 2 years later for all new vehicle registrations.



ADDITIONAL MEASURES TO COMPLEMENT THE LIMIT VALUE REDUCTIONS

- › In any case, it is acknowledged that the benefits can be maximized by accompanying the improvement of sound limits with **additional measures**
 - › additional sound emission provisions (ASEP) – improvements in test procedure
 - › better enforcement of regulation – in service conformity checks
 - › anti-tampering measures – illegal exhausts
 - › influence on riding behavior

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