July 2017

PRESENTATION OF

INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS

ASEP Development

Strategy for ASEP Revision 2

Development of a Physical Expectation Model Based on UN R51.03 Annex 3 Performance Parameters

4th GRB Informal Working Group Meeting
Washington DC

Presentation Content

- Intention of ASEP / Scope
- Proposal for a road map for the revision of ASEP
- Reflections on demands of Germany on ASEP
- OICA Position on the Revision of ASEP
- Approach to a technical solution for a new ASEP concept
- ASEP Application Scheme
- Setup of a test program to collect necessary data

Intention of the ASEP Revision / Scope

- **Development of a new ASEP concept**
  - Overcome shortfalls of current test and assessment methods.
  - ASEP efficiency shall be improved. Better control by less work load
  - Vehicles shall be tested closer to their real use
- **Application on vehicles with ICE used for propulsion of the vehicle**
  - Assessment of the sound emission of an ICE power train over vehicle speed, engine speed and engine load
- **Integration of Active Sound Systems such as**
  - Multi-gas-flow exhaust and intake systems
  - Sound System (Sound generators, Active sound, etc..)

Road Map

07/2017:	Presentation of a concept for ASEP and adoption of a work plan for the next two years
Until 06/2018:	Collection of test data ➢ Create a database of vehicles as a work tool to check the new ASEP concept ➢ Generate additional data for the creation of a sound prediction model Finalize the develop a new ASEP test
From 06/2018:	Make the first draft Regulation text Collect more data for validation and fine tuning
Within 2019:	Fine tuning of the ASEP concept Finalize the Regulation text Administrative consideration (Application of ASEP)
End of 2019:	Present Proposal to GRB

Application of ASEP – Demands from Germany

- ASEP is requested to become mandatory for type approval (TA) and Conformity of Production (CoP)
- Germany has offered two possible ways for the construction of ASEP:
  1. A limited control range to account for the restrictions in testing that is actually given for most exterior noise test facilities
     1. The control range will approximately stay as it is today
     2. As this control range cannot cover all driving situation which occur on public streets (excluding highways), Germany deems it necessary to introduce definitions for defeat devices.
        ➔ Defeat devices or cycle beating functions are the consequence of a non all-embracing control range.
  2. A wide control range that covers almost any driving situation on urban, suburban and country road, but not highways
     1. The control range will be expanded and it might no longer be possible to carry out tests over the full control range, especially not on those, that are close to production facilities and used for CoP
     2. As the control range covers all situations, defeat device and cycle detection definitions become irrelevant.

OICA Position on the Application Options from Germany

- OICA is concerned that
    - Already the actual control range is such wide, that it is almost impossible to test all conditions. Manufacturer cannot entirely verify the compliance under all conditions. The work load is already too high.
    - The requested extension of the control range will worsen the situation. It will become impossible to check extreme conditions (e.g. high speeds at high gears). The work load will become even higher, the reassurance to comply lower.
    - Definitions for defeat devices and/or cycle detection provisions in the noise field will lead to unmanageable interactions with the regulatory field for gases emissions, which can - most likely will - lead to contradictory requirements.
- It is very difficult at the moment for OICA to make the trade-off between the two options offered by Germany.
- Therefore OICA suggests to focus in a first step on the development of an ASEP test, that is applicable to any driving situation
    - Once the test is completed, one can better estimate the consequences

Essential Requirements from OICA for the ASEP Revision

- ASEP needs simplification.
  - We must restrict the test and evaluation methods to only one ASEP assessment.
  - The tests must be simple to limit the work load, to enable as well less trained and experienced people to carry out CoP measurements
- With electronic control systems a single point measurement is just representative for the particular test condition.
  - How many tests are necessary to have an image of the vehicle?
  - We need to define, what process a manufacturer will have to carry out to be sure that compliance is achieved without testing the whole control range.
- Normal products should not have any problems in fulfilling ASEP.
  - ASEP must be designed in a way so that standard vehicles which are uncritical in the spirit of ASEP are either exempted or can easy fulfil the ASEP.
- In future we will have more products that will no longer have discrete gears in the classical understanding.
  - The ASEP test must be able to assess their sound emission in a proper way.
- We need to consider indoor facilities as alternative for outdoor testing
  - Indoor testing should be acceptable, if outdoor testing will stay as reference in case of doubts.

Additional Requirements for the ASEP Revision

- We have to acknowledge that in difference to the classical gases emission field, an large group of the society is addicted to good sound and emotional feedback.
  - Since automobiles are built, there has been a market to customize the sound according to the individual taste of the owner.
- OICA believes that many complains on abnormal sound emission in traffic cannot be associated to OEM equipment and calibration.
  - There are lot of evidences that OE vehicles are manipulated so that the sound is very often customized and tuned-up.
- Any revision of ASEP must have as well considerations on
  - Control of aftermarket
  - Third party interference with the calibration and software of active sound devices

Evaluation of the Actual ASEP Assessments

SLOPE-ASSESSMENT

PRO

- Built directly on the individual vehicle technology
- Accounts for the probability of occurrence, by applying an "edging" of the limitation curve starting from the anchor point

CONTRA

- Requires a lot of testing to create the limitation curve
- One limit curve based on maximum acceleration performance might be too high for partial throttle condition
- Not applicable to gear higher than gear i of the type approval due to conflicts with tyre rolling sound.
- The maximum slope of 5 dB(A) is not valid for higher gear
- Only applicable for stable transmission ratios

L_{URBAN}-ASSESSMENT

PRO

- Design neutral
- No pre-testing required to create a limitation curve
- Each tested point can be assessed directly
- Capable for partial load testing

CONTRA

- Not applicable for accelerations below a_{urban}, which limits gear and partial load accelerations
- Reference of a_{urban} is only valid at 50 km/h
- Compensation for vehicle speed is too simple

REFERENCE SOUND

PRO

- ???

CONTRA

- Design dependent test
- Not future safe
- Follows the believe that a single point could predict a whole sound map.

Suggestion for the Revision of ASEP

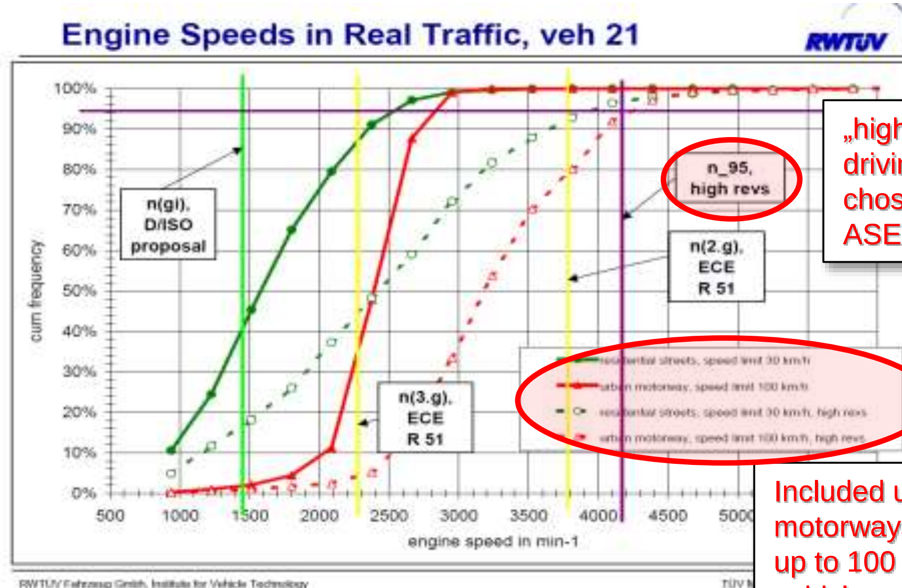
- The "Slope-Assessment" and the "L_{urban}-Assessment" should be merged together to a new single assessment method, the "Sound Estimation Model"
- Requirements to that new model:
  - Must be applicable to all vehicle design based on ICE technology
  - For a single run must be an immediate answer, whether or not the vehicle is in compliance at that tested point.
  - The model should be applicable to any operation condition with no restrictions to engine speed, vehicle speed and engine load.
- The question how to set the control range is then a tradeoff between testing capabilities and environmental needs.

➔ The next slides introduce the principles of this new model for consideration.

Intention of ASEP - Reflected in the 1st WD of UN R51.03

TRANS/WP.29/GRB/2005/2/Rev.2

The sound emission of the vehicle under normal driving conditions different from the conditions of the type approval test in Annex 3 shall not differ considerably from what can be expected from the type approval test result for this specific vehicle with regard to technical practicability. This is fulfilled if the requirements of Annex 10 are met.



„high rev driving" was chosen for ASEP

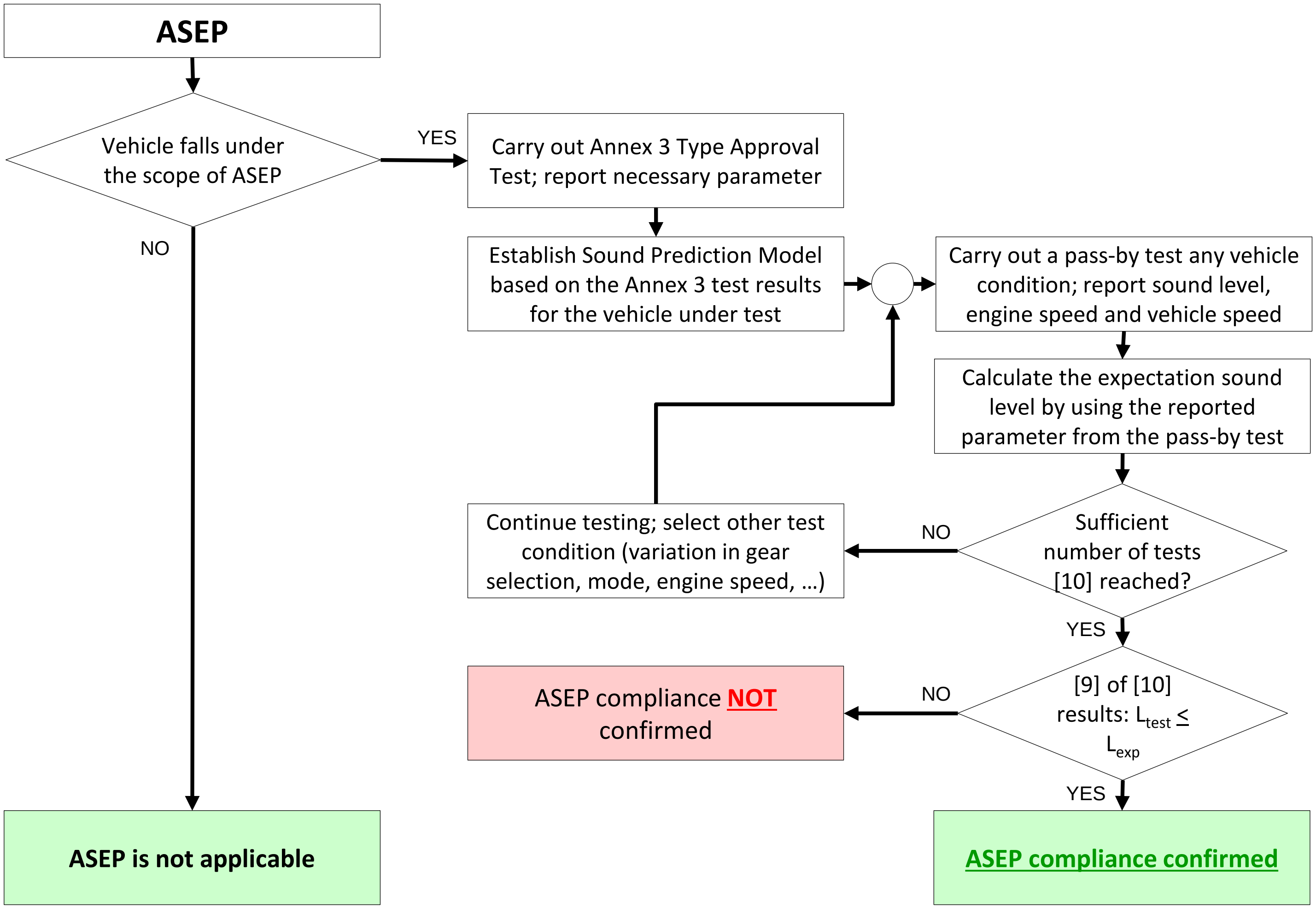
Included urban motorways with up to 100 km/h vehicle speed

Definition need

Should be based on Annex 3 data

Develop a physical model

ASEP Application Scheme (Follow Option 2 of Germany)



Construction Principle for the Sound Model

- The reference for the model should be based on type approval test data as it is already today given for the Slope-Assessment and L_{urban}-Assessment in the current ASEP.
- The edging at the “Slope-Assessment” accounts for the various importance of the operation conditions within the control range:
  - High engine speeds may occur in traffic but have statistically no relevance.
  - Very low engine speed may be favorable to be used in traffic, but are as well less used compared to the type approval condition. In addition, at these low engine speed conditions is the emitted sound much lower and creates per se less problems.

Sound Model Basic Considerations

1 Tyre

2 Base Mechanics

- The two elements together create the “physical” base model of a behavior of any internal combustion engine vehicle.
- If linked to a type approved reference point, e.g. Lcrs,rep and Lwot,rep, these models will form the minimum sound emission of a vehicle.
- **These two elements are related to the vehicle design and shall not cause a non-compliance.**

3 Dynamics

- This model is the dynamic “add-on” to the minimum model formed by 1 and 2 .
- This is the parameter for adjustment to a maximum acceptable sound dynamic.
- This model 3 can be linked to PMR and/or the acceleration performance of a vehicle.

Reference Values and Available Data

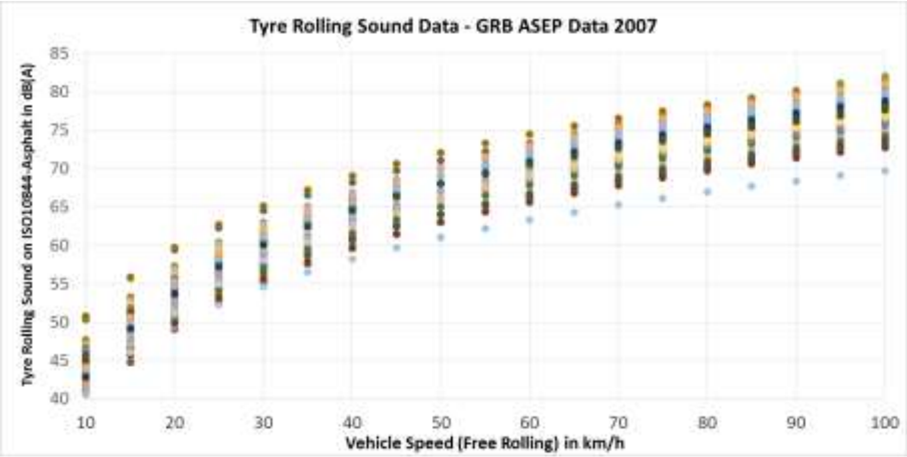
- The Annex 3 test results $\mathbf{L_{crs,rep}}$ and $\mathbf{L_{wot,rep}}$ can be used as reference for the elaboration of the "expectation model".
  - $\mathbf{L_{crs,rep}}$ is considered to be dominated by the tyre rolling sound with some contribution of the power train base mechanics and very little contribution of the high dynamic sound sources.
  - $\mathbf{L_{wot,rep}}$ can be taken as a link for the dynamic model, but needs adjustment for the contribution for tyre rolling sound and power train base mechanics.

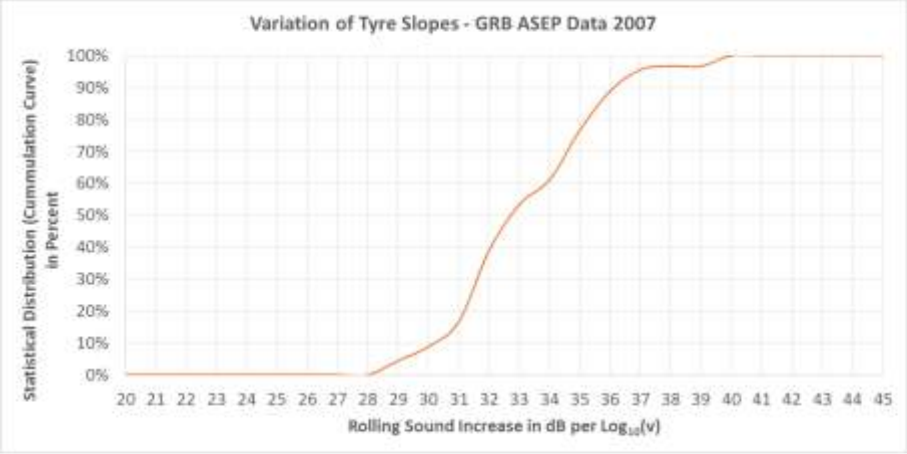
- Further data available from Annex 3 are
  - PMR, $a_{wot,ref}$ a_{urban}, L_{urban}
  - Gear / gear ratio (i, i+1, i+2,…)
    - Vehicle speed $v_{BB'}$
    - Engine speed $n_{BB'}$
    - Acceleration $a_{AA'-BB'}$ or $a_{PP'-BB'}$

- These data can be used as a basis for the three models.

1 Tyre Rolling Sound

- Tyre rolling sound is not considered ASEP critical.
  - Tyres are covered under UN R117.
- But, certified tyres can have
  - a large variation with regard to their sound increase versus driving speed
  - very different load dependencies
- **The particular behaviour of a tyre used during type approval for UN R51.03 is unknown, the variation in tyre behaviour is considered as necessary tolerance in the prediction model.**





1 The “Prediction Model” for the Tyre Rolling Sound

- The chosen function is:

$$L_{TR,NL} = slope_{TR} * LOG_{10}(v_{test} / 50) + L_{REF,TR}$$

There will be a **$slope_{TR,min}$** for test speeds below 50 km/h and a **$slope_{TR,max}$** for speeds above 50 km/h.

The differentiation accounts for the unknown behaviour of the tyre rolling sound.

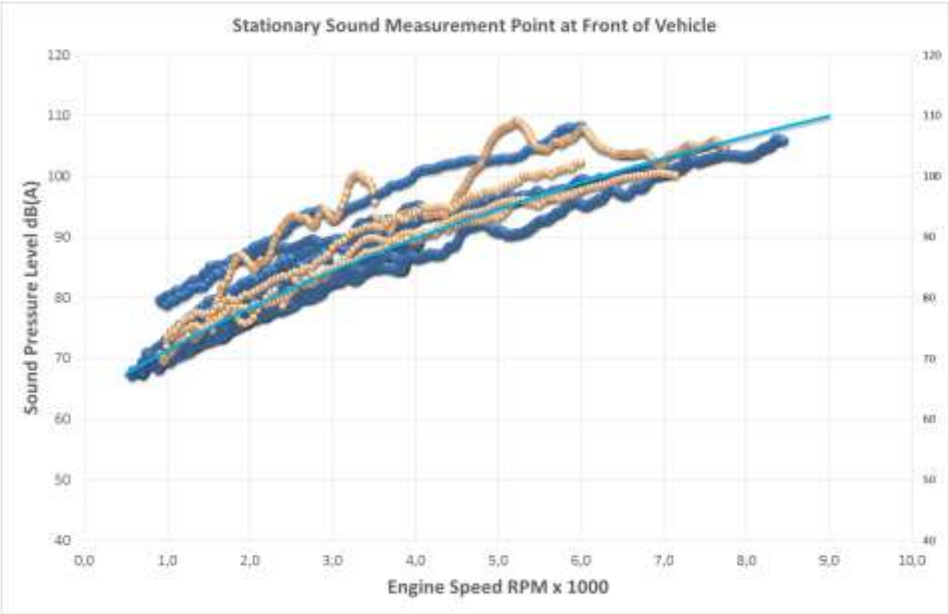
The **$L_{REF,TR}$** is a fractal of the steady speed test result of Annex 3 **$L_{CRS,REP}$**.

$$L_{REF,TR} = 10 * LOG_{10}(10^{(x\% * L_{crs,rep}/10)})$$

How much percent (**x%**) of the steady speed result is used in general needs further investigation and might be defined differently for the vehicle categories.

2 The Base Mechanic Model for the Power Train

- For the development of the mechanic model, data are taken when the impact of tyres rolling sound is neglect able.
- This could be an engine run-up in stationary condition or cruise-by tests at very low gears.
- Such data are not available from the GRB ASEP 2007 database.
- The important information is the slope characteristic over engine speed.



- Excel does provide only a limited capability of fitting curves, that might not be sufficient accurate.
- The recommended model is a shifted logarithm to adapt the slope characteristics better to the real sound behavior of the engine.

2 The "Prediction Model" for the Power Train (No Load)

- The chosen function is:

$$L_{pt,NL} = slope_{PT,NL} * LOG_{10}(n_{test} + n_{shift}) / (n_{wot,ref} + n_{shift})) + L_{REF,NL}$$

A $slope_{TR,min}$ for test engine speeds below $n_{BB',REF}$ and a $slope_{TR,max}$ for speeds above $n_{BB',REF}$ is introduced.

The differentiation accounts for the unknown behaviour of the power train.

An engine speed shift component n_{shift} is introduced for an optimized curve fitting for the power train model

The parameter $L_{REF,NL}$ is the remaining part of the steady speed test of Annex 3 $L_{CRS,REF}$ that was not used in the tyre model before.

$$L_{REF,NL} = 10 * LOG_{10}(10^{((100\%-x\%)*L_{crs,rep}/10)})$$

In addition, a small correction for the gas flow is necessary.

3 The Dynamic Model

- The dynamic model follow the same construction principles as the power train base model, but with a offset for the high dynamic components.
- The border slopes were set lower, as typically the no load condition and the full load condition come closer at high engine speeds.
- The reference value $L_{pt,FL}$ is calculated as:

$$L_{PT,FL} = \text{slope} * LOG_{10}(\, n_{test} + n_{shift}) / (n_{wot,ref} + n_{shift})) + L_{REF,FL} + \Delta L_{partial}$$

See next slide

The border slopes $Slope_{min}$ and $Slope_{max}$ are typically lower compared to the base model slopes.

The same shifting principle is applied as for the base mechanic system.

Selected parameter:

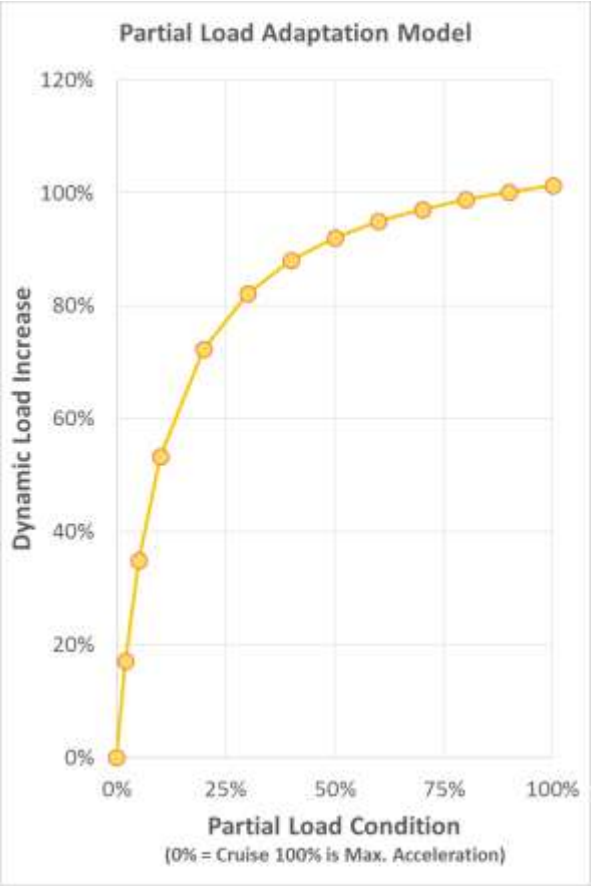
$L_{REF,FL} = 10*\log(10^{L_{wot,ref}/10} - 10^{L_{crs,ref}/10})$ - **DYN**

The **DYN** value is the dynamic of whole power train system but typically dominated by the gas flow. In a first approach it is linked to the best acceleration performance of the vehicle.

DYN = $30 * LOG\,(a_{max} / a_{urban}) + (L_{wot,ref} - L_{crs,ref})$

The Partial Throttle Model $\Delta L_{partial}$

- For sound assessment under partial load condition, it is necessary to consider the sound change between no load (cruising) and maximum load (full throttle).
- We need to consider what could be a suitable signal information
  - Position of the accelerator?
  - Opening of the throttle valve?
  - Acceleration versus maximum acceleration?
  - Other…?
- While in Annex 3 the combination of the constant speed test and the acceleration test is linear, we need for ASEP a different model with a high increment from low load positions with an early load saturation at approximately 50% throttle condition.
- More research is needed.
- As a simplification, the full throttle curve might be applied as well to any partial throttle condition.



Integration of all Modules

- Before the ASEP evaluation, it is necessary to carry out the Annex 3 type approval test
  - The parameter to be reported are: L_{wot} and L_{crs} from the lower or single gear, the acceleration (actually PP-BB), the vehicle speed v_{BB}, the engine speed n_{BB}.
  - For the gear ratio, the maximum acceleration must be known to determine the load condition.

- The expectation level is then calculated

$$L_{exp} = 10 * LOG\,(10^{0,1*L_{tyre}} + 10^{0,1*L_{pt,NL}} + 10^{0,1*L_{pt,FL}}) + MARGIN$$

- Compliance is achieved when

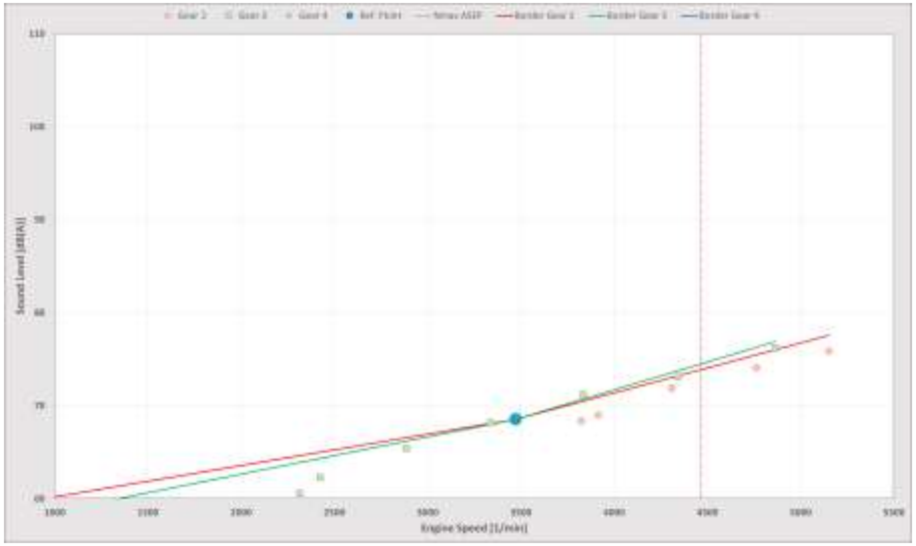
$$\mathbf{L_{test}}\,(v_{test}, a_{test}, n_{test}) \leq \mathbf{L_{exp}}\,(v_{test}, a_{test}, n_{test})$$

Validation of the model

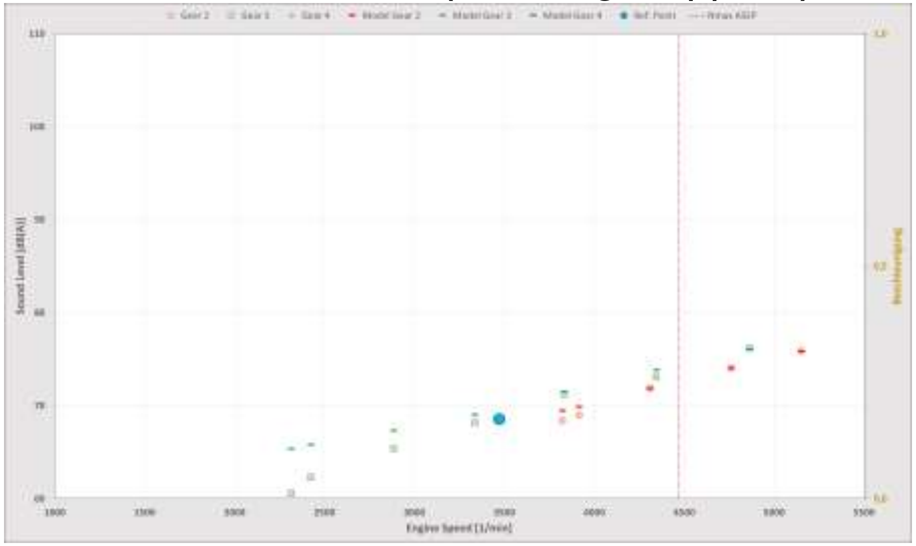
- The model was applied in a first step to the **GRB ASEP DATABASE from 2007**.
- For this application a selection of parameters coming from available data was made.
- Different to the actual ASEP "Slope-Assessment", the model
  - it is more simple in application, as each individual point can be assessed directly.
  - Does not need extra tests to elaborate a limitation curve for a discrete gear ratio.
  - provides sensible results for MT, AT and for CVT
  - is "fair" and plausible for most vehicles.
- Different to the actual ASEP "L_{urban}-Assessment", the model
  - provides results as well for accelerations below a_{urban}.
  - is accurate with regard to the speed variations in a large range
- It is important to keep in mind that the GRB ASEP DATABASE 2007 contains sometimes data, which are not consistent
- This model is only a first step. Further evaluation is needed.

Example 1: Standard Car (Vehicle 1-11)

Actual ASEP Result (No Margin applied)

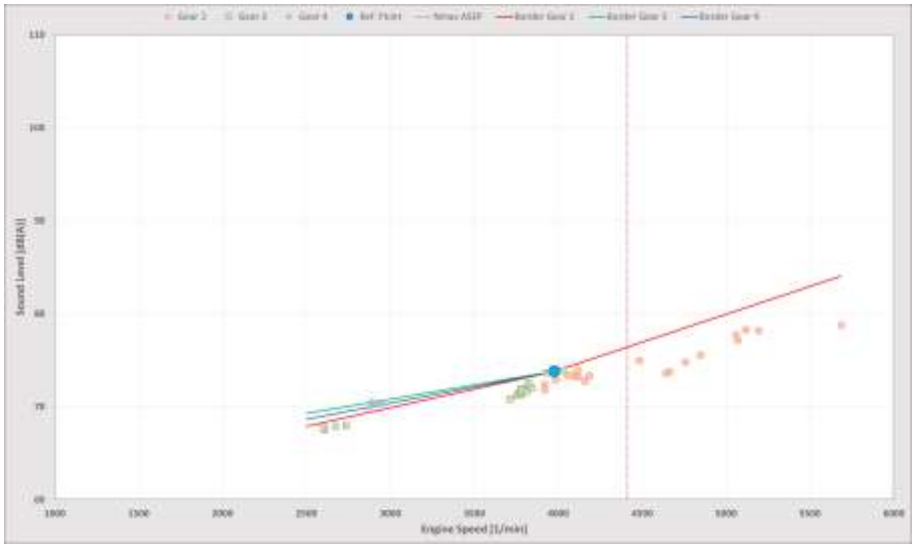


Prediction Model (No Margin applied)

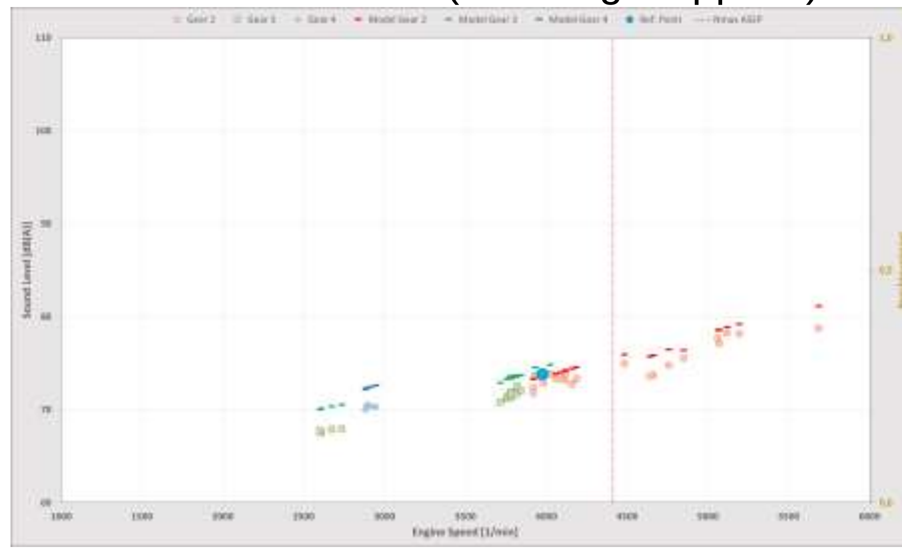


Example 1: Standard Car (Vehicle 99-15)

Actual ASEP Result (No Margin applied)

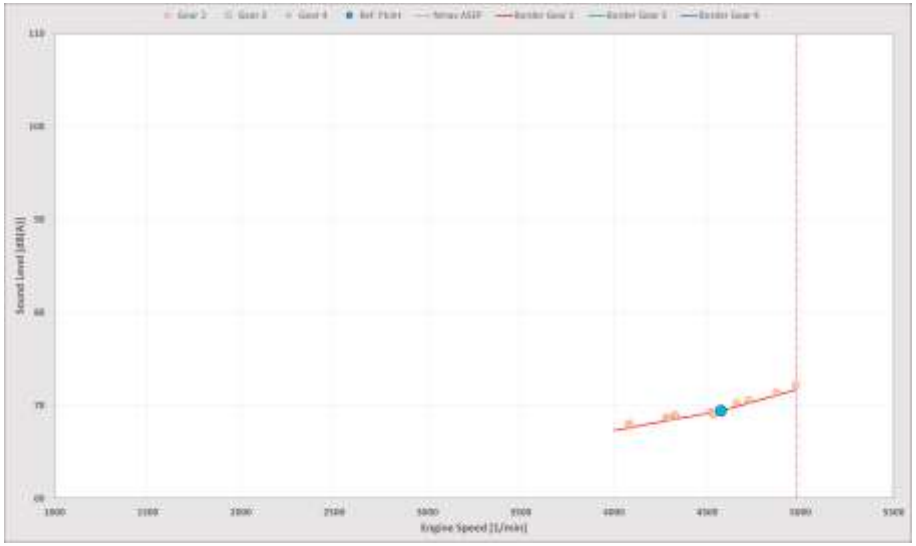


Prediction Model (No Margin applied)

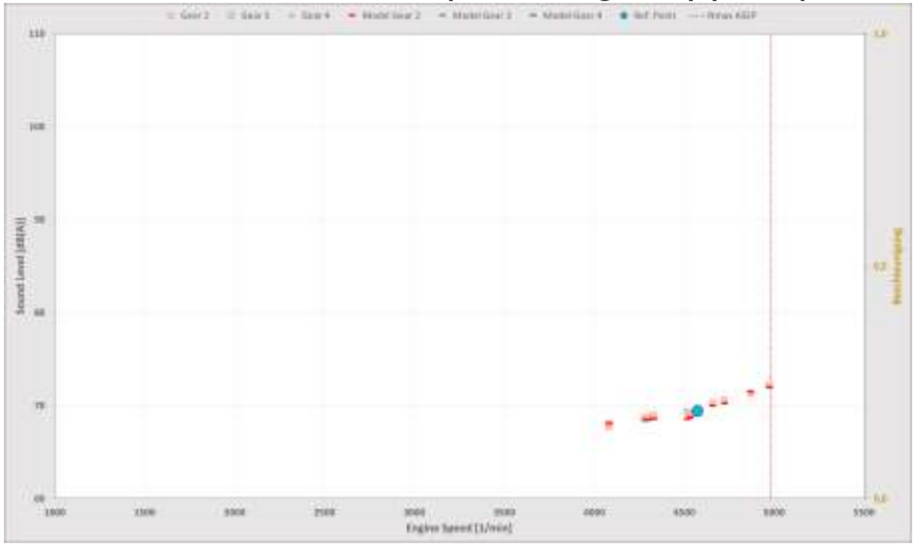


Example 1: CVT Car (Vehicle 1-12)

Actual ASEP Result (No Margin applied)



Prediction Model (No Margin applied)



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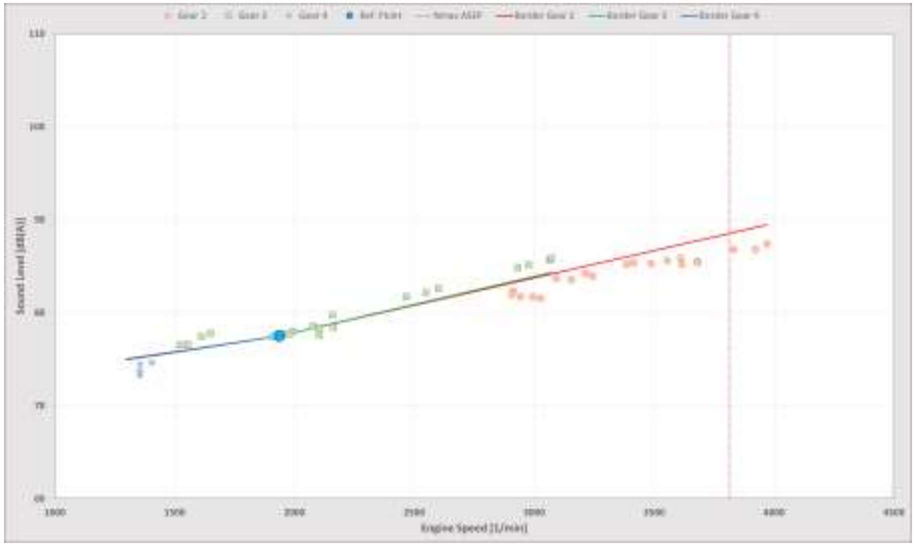
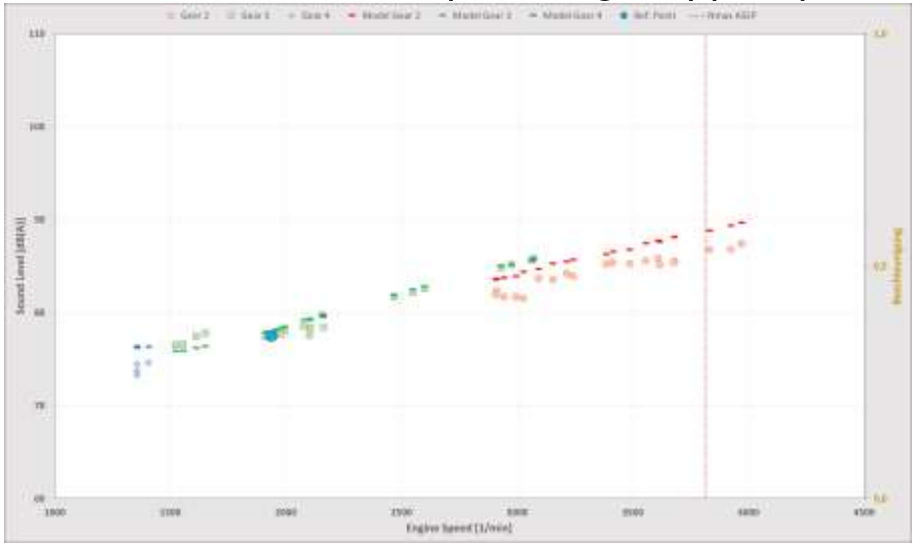
Example 1: Sports Car (Vehicle 200-10a)

Actual ASEP Result (No Margin applied)

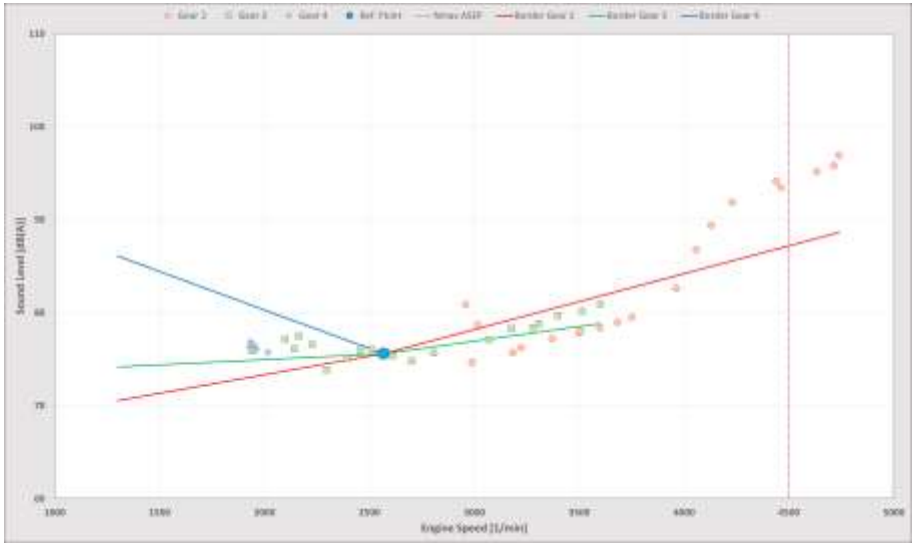


Prediction Model (No Margin applied)



Example 1: Sports Car Extreme (Vehicle 200-09a)

Actual ASEP Result (No Margin applied)



Prediction Model (No Margin applied)