6th November 2018

**PRESENTATION OF**

OICA

**INTERNATIONAL ORGANIZATION OF MOTOR VEHICLE MANUFACTURERS**

# Partial Load & Performance Modelling

## ASEP Revision 2.0

## Definition for Partial Load Driving

- Partial load driving means any driving condition which provides positive acceleration greater than 0.3 m/s² between cruising and maximum load driving for a specific engine condition.
- Cruising is defined as low acceleration with a variation of +/- 0.3 m/s² around zero acceleration.
  - The acceleration 0.3 m/s² is derived from the allowable tolerance of +/- 1 km/h for the steady speed test according to UN R51.03 Annex 3 paragraph 3.1.2.1.6.

    $$a_{crs} = ((50^{+1km/h}/3.6)^2 - (50^{-1km/h}/3.6)^2) / (2*(20 + l_{veh}^{*)}) = 0.30\ m/s^2$$

    $^{*)}\ L_{veh} = 5m$

- Maximum load driving is the maximum achievable acceleration for a specific engine operation condition.

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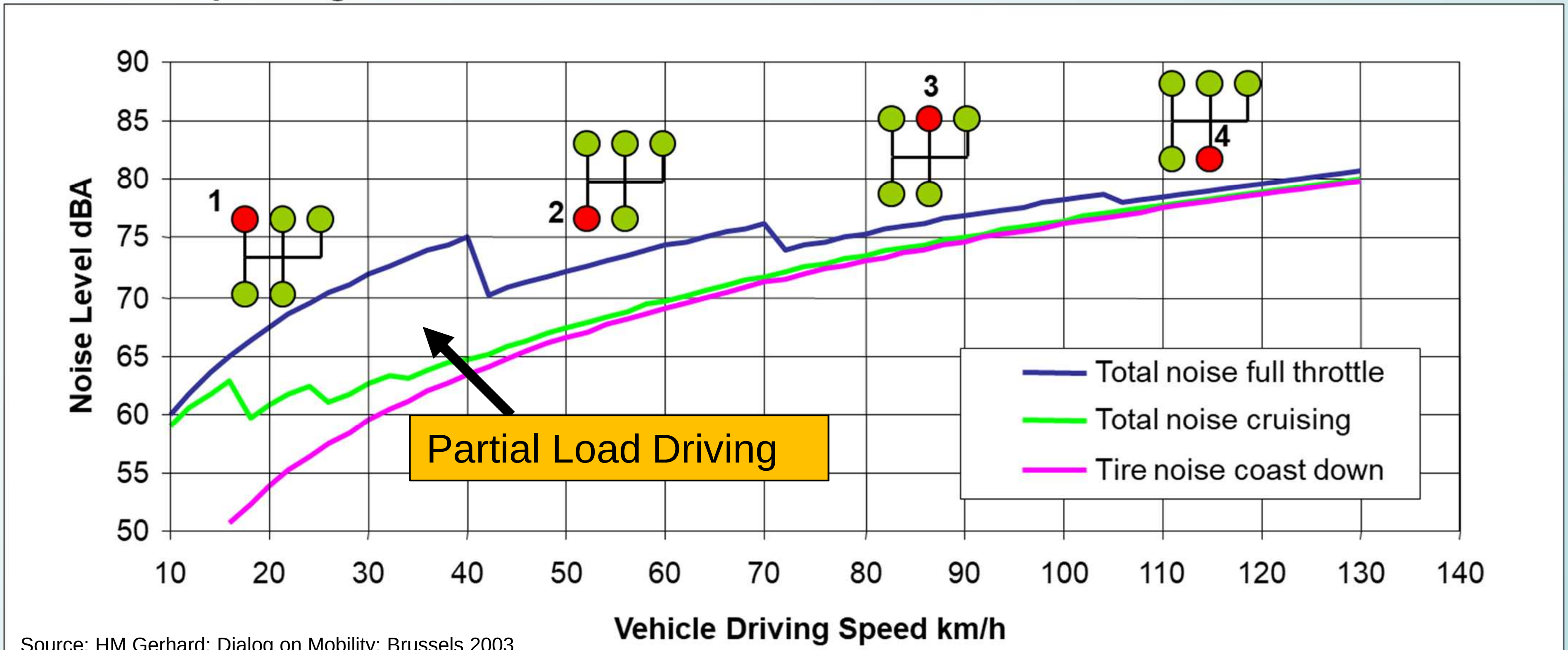
# Definition for Partial Load Driving

**mid class passenger car**

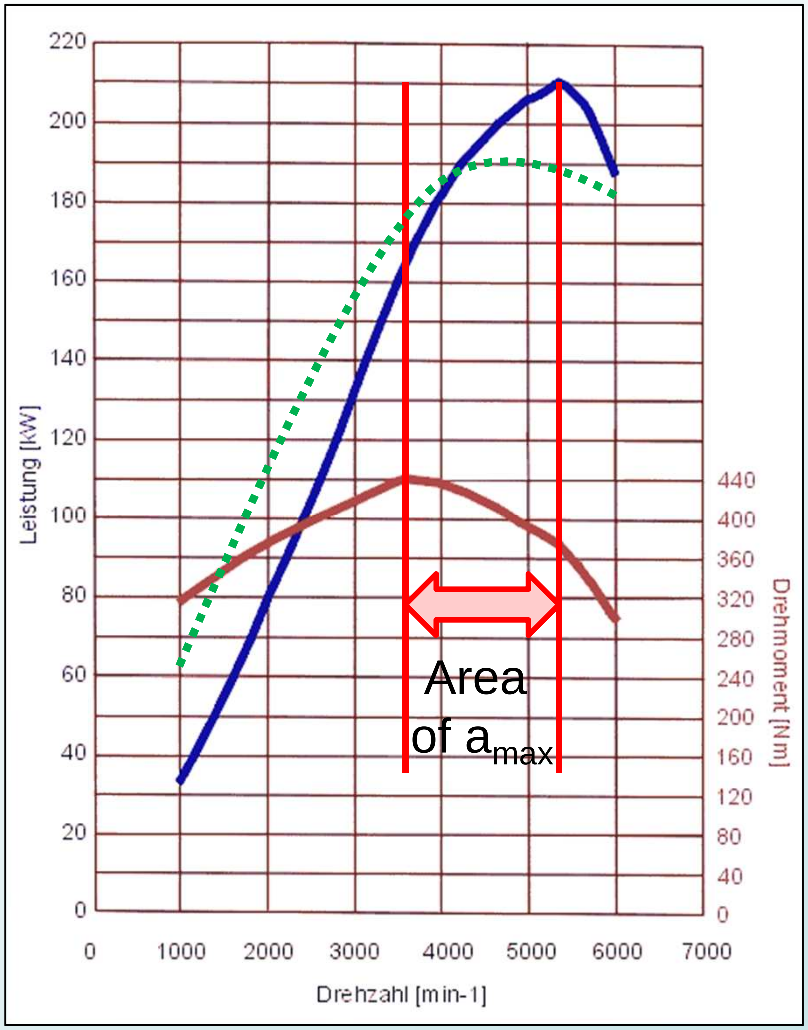



Source: HM Gerhard; Dialog on Mobility; Brussels 2003

## What Parameter to Chose for the Control of the Partial Load Area?

- The position of the throttle?
  - The throttle is a specific design of petrol engines, other technologies do not have a throttle.
  - The percentage of opening of the throttle is directly related to the achievable performance. The throttle diameter is tailored to maximum gas flow at rated engine speed.
  - This means a given percentage of opening of the throttle represents different loads at different engine speeds
- The percentage of depressing the accelerator pedal?
  - Vehicles have electronic accelerator pedals. The signal response is NOT linear to the engine. The response is mode dependent and integrates driving comfort, fuel economy and performance response.
- The achieved acceleration?
  - The achieved acceleration must be weighted against a reference value. However the reference is dependent on the operation condition of the engine and the gear/gear ratio engaged.

## Acceleration Performance versus Engine Speed




Maximum achievable acceleration dependent on the engine speed

- The maximum achievable acceleration is dependent on the torque and power available at a discrete operation condition.
- This means the acceleration is dependent on the gear where the acceleration happens and the engine speed which is taken representative for the acceleration phase:

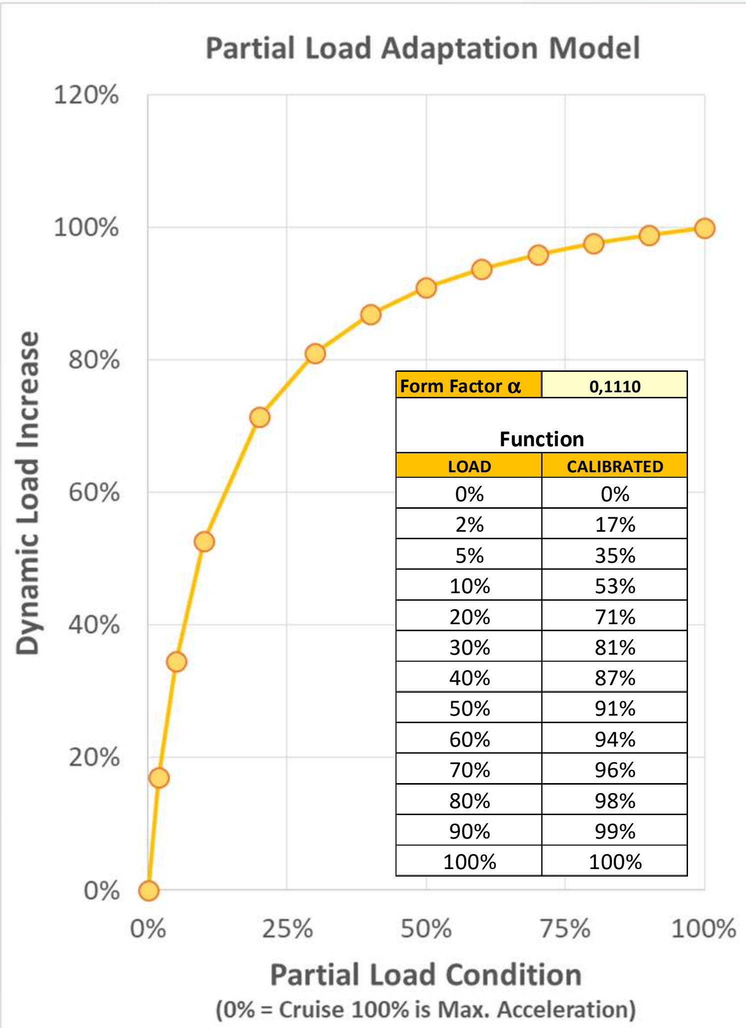
$$a_{max,test} = f(i_{test}, n_{BB'})$$

- This behaviour is taken into consideration under the Sound Transient Function.

## Simplified Approach

- The acceleration for a specific gear is assumed constant.
  - This means it is assumed that a vehicle would have always the same maximum acceleration in a given gear over the whole engine speed range.
  - The torque and power curve are considered under the Sound Tranient Function via the form factor.
- The partial load is simulated by using the acceleration performance relative to a reference acceleration in one specific gear.
  - For other gears or gear ratios, the reference acceleration is adjusted via the gear ratio.
  - Therefore it is necessary to determine once an reference acceleration, preferably in a low gear, such as 2nd gear.

## Sound Transient Function: Link Between Load and Sound




| Form Factor α | 0,1110 |
|---|---|
| Function | |
| LOAD | CALIBRATED |
| 0% | 0% |
| 2% | 17% |
| 5% | 35% |
| 10% | 53% |
| 20% | 71% |
| 30% | 81% |
| 40% | 87% |
| 50% | 91% |
| 60% | 94% |
| 70% | 96% |
| 80% | 98% |
| 90% | 99% |
| 100% | 100% |

The Sound Dynamic $\Delta \mathbf{L}_{\mathbf{DYN}}$ is the acoustic dynamic between no load and full load.

For the simulation, a hyperbolic function was chosen to adjust for engine speed dependent maximum acceleration and for the typical non-linear transient between no load and maximum load.

Formula:

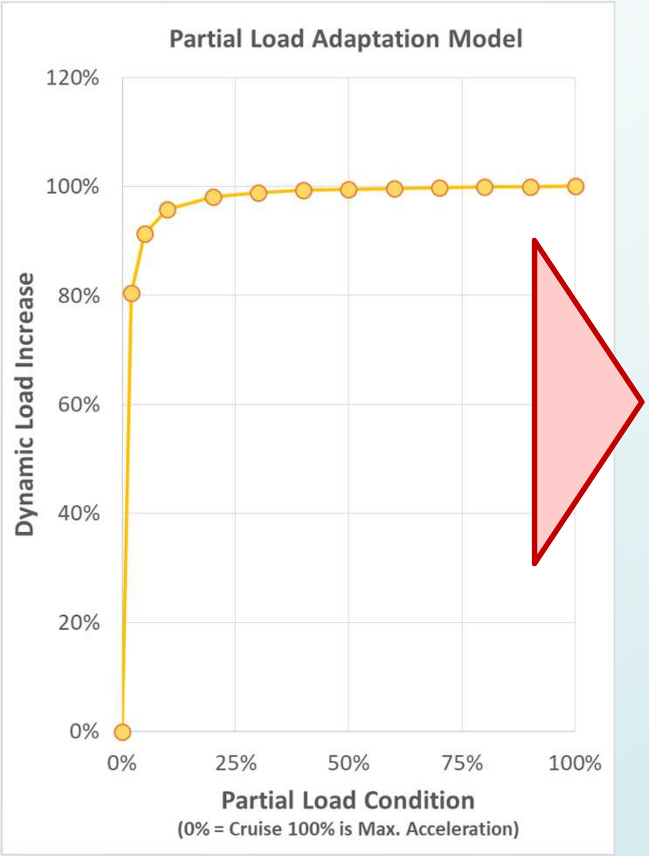
$$\Delta \mathbf{L}_{\mathbf{DYN,PL}} = \Delta \mathbf{L}_{\mathbf{DYN}} \left(\left(1 - \alpha/(LOAD+\alpha)\right) / (1-\alpha)\right) / \omega$$

Calibration Part $\omega$

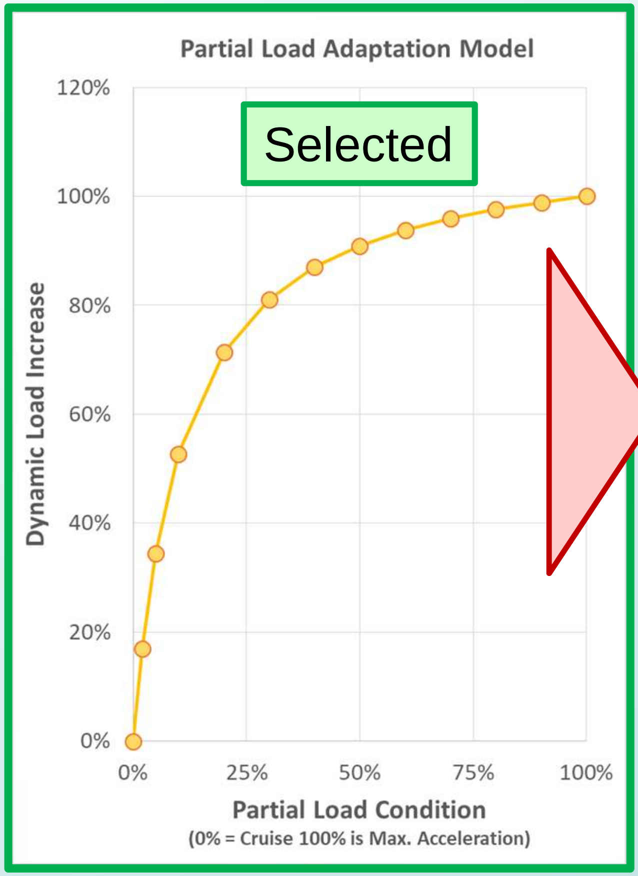
$$\boldsymbol{\omega} = 1/(1-\alpha) - \alpha/(1-\alpha^2)$$

The shape of this curve can be adjusted by the **form factor** α in a wide range for best fitting

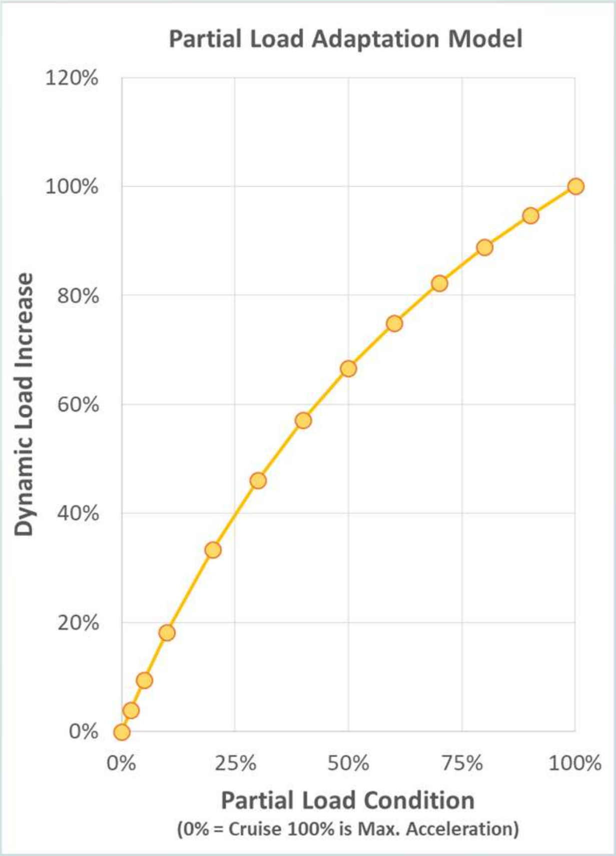
## Adjustable Partial Load Transient via the Form Factor α




α = 0,005




α = 0,111




α = 1,000

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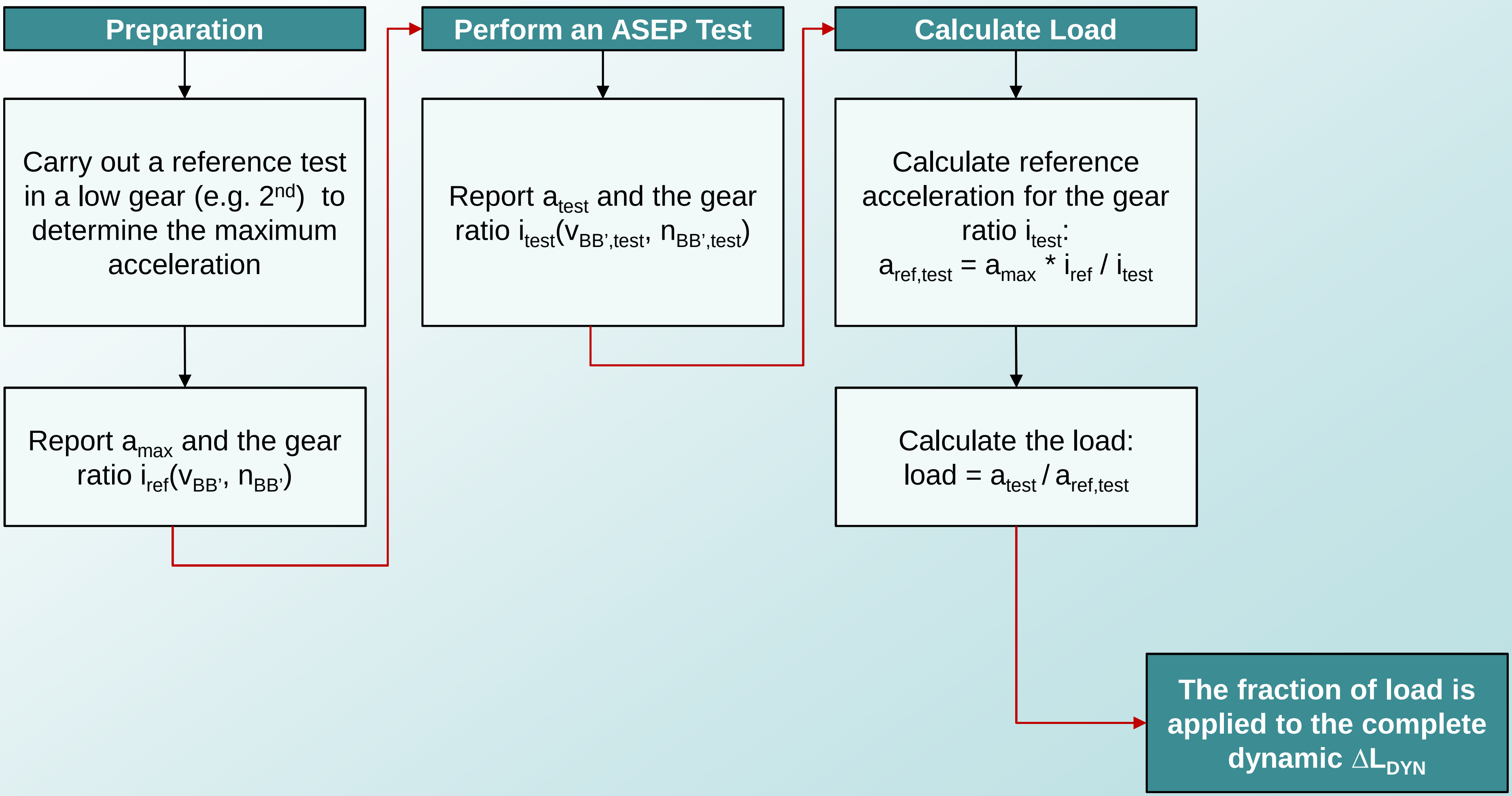
# Determination of the Load for a Discrete Test



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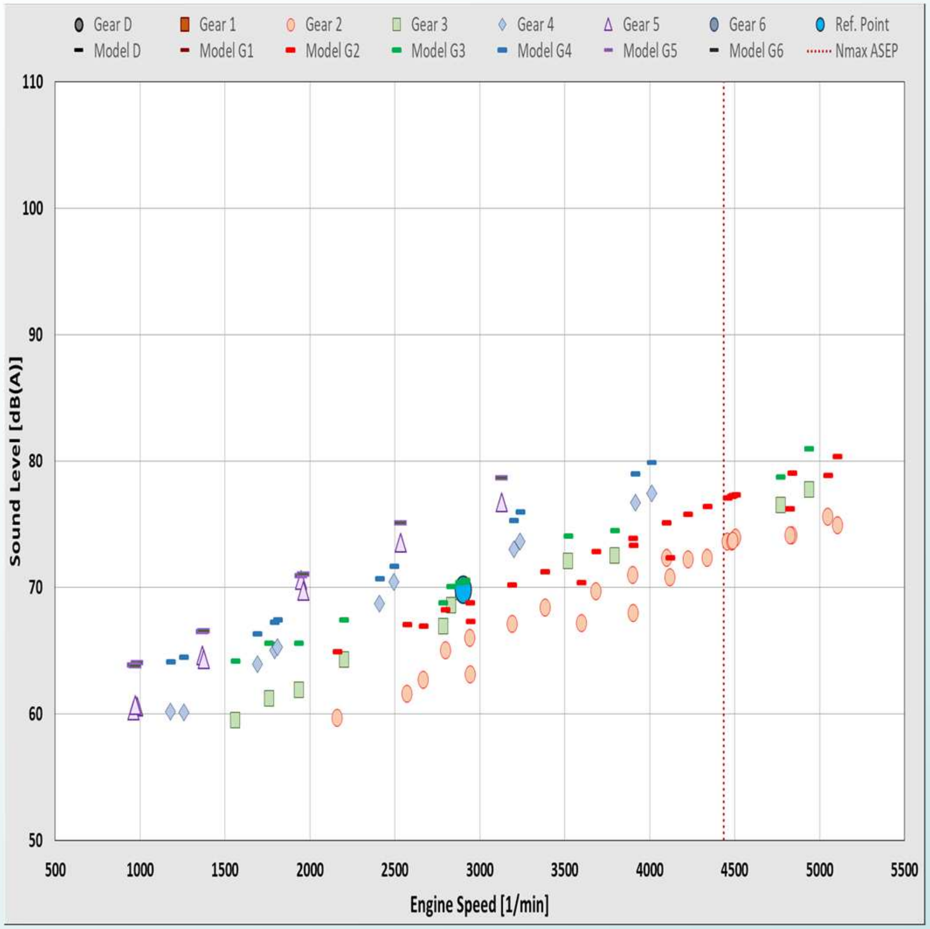
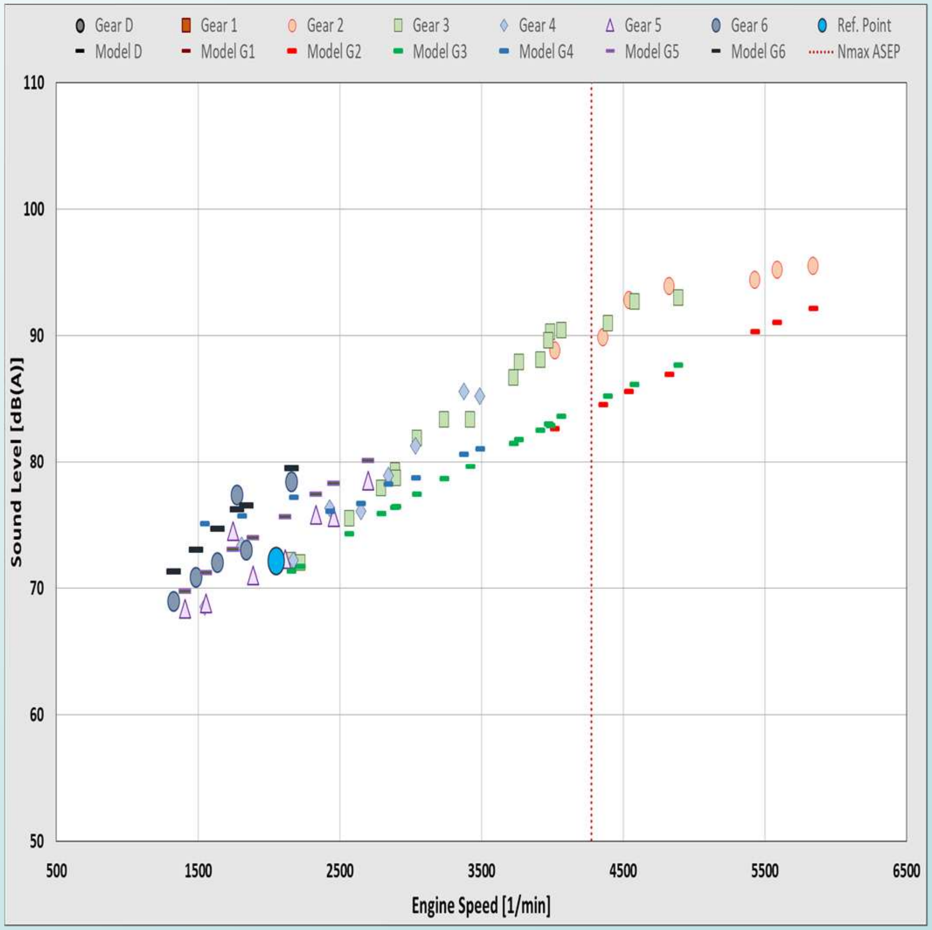
**Integration of v x a – Concept into the sound model**

- The sound model simulates the general sound sources tyre/road, power train mechanics and dynamics based on type approval test results.
  - This model is based on engine speed and vehicle speed and does not consider performance aspects of a vehicle.
  - However, behind a tested operation condition the acceleration can be very different and thus as well the sound emission of vehicles.
- In 2018 a separate assessment model for performance was developed.
  - This models helps to differentiate between normal and extreme driving conditions.
  - However, this model cannot adequately assess partial load and cruising, as acceleration close to zero will lead to very low although the vehicle speed and thus the tyre/rolling sound could be very high.

# Actual Sound Model – Based on IWG ASEP Presentation Tokyo 2017




Example 1 (normal vehicle)




Example 2 (high performance vehicle)

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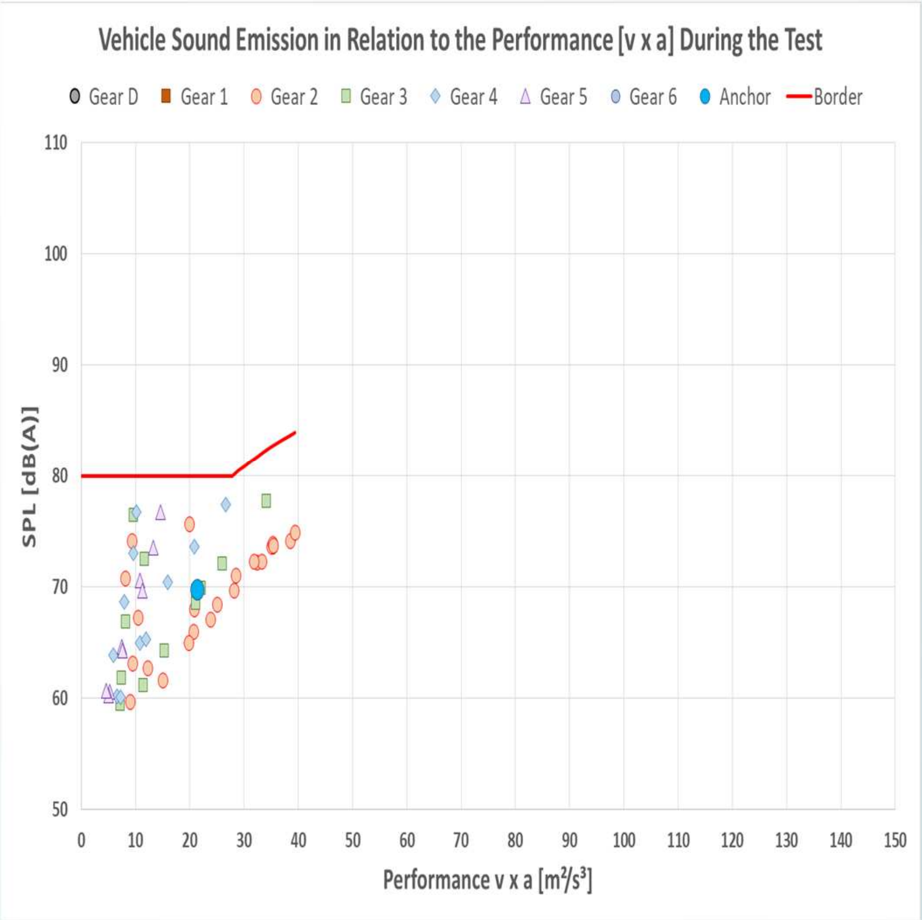
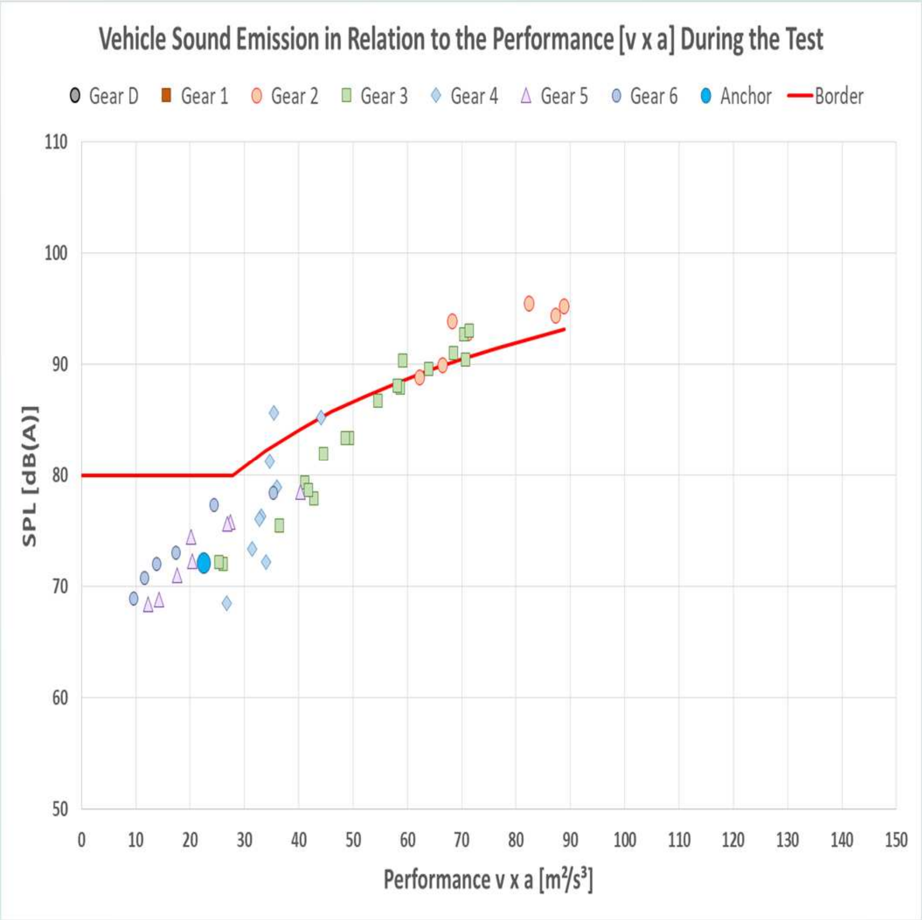
# Performance Model - Based on IWG ASEP Presentation Brussel 2018




Example 1 (normal vehicle)




Example 2 (high performance vehicle)

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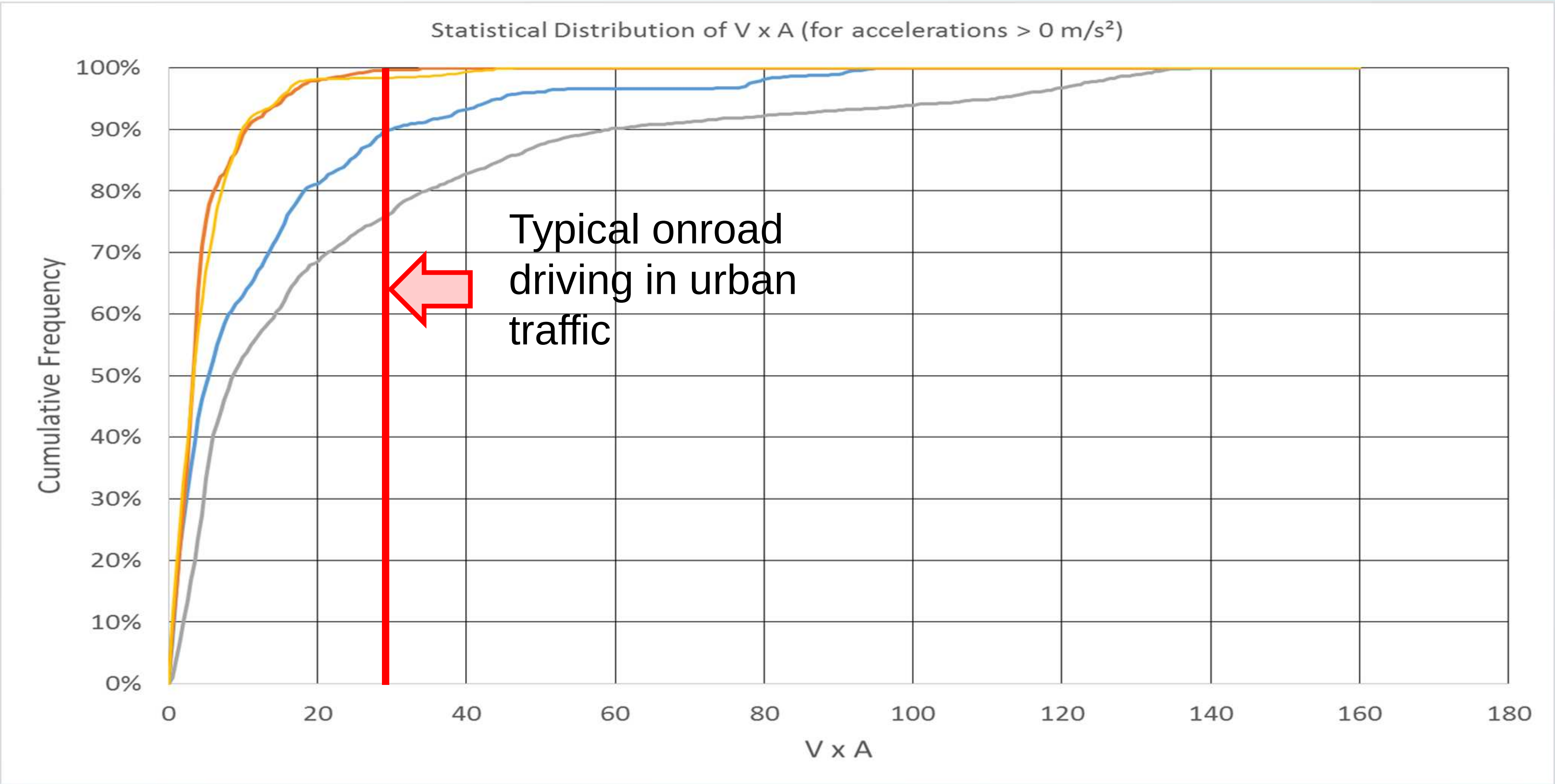
# Real Driving Performance (OICA Presentation February 2017)




- For driving within the typical onroad driving, performance cannot be added, as UN R51.03 Annex 3 is considered to be almost design neutral.
- ASEP Annex 7 and especially the revision 2.0 goes beyong that neutral area.

## Integration of v x a – Modelling Approach (1)

- For the modelling the performance is calculated by using the vehicle speed $v_{BB'}$ and the acceleration $a_{test}$.
- The performance is calculated by:

$$va_{test} = v_{BB'} / 3.6 * a_{test}$$

- For normal onroad driving in urban areas the reference performance is determined by:

$$va_{ref} = v_{BB',Annex3} / 3.6 * a_{max,Annex\ 3} \quad \text{with} \quad v_{BB',Annex\ 3} = 50\ km/h$$

$$a_{max,Annex\ 3} = 2.0\ m/s^2$$

- The reference performance is $va_{ref} = 28.7\ m^2/s^3$

## Integration of v x a – Modelling Approach (2)

- For performances lower than the reference acceleration, there will be no effect to the actual model.
- For performances greater than the reference acceleration, additional sound quotation is applied:

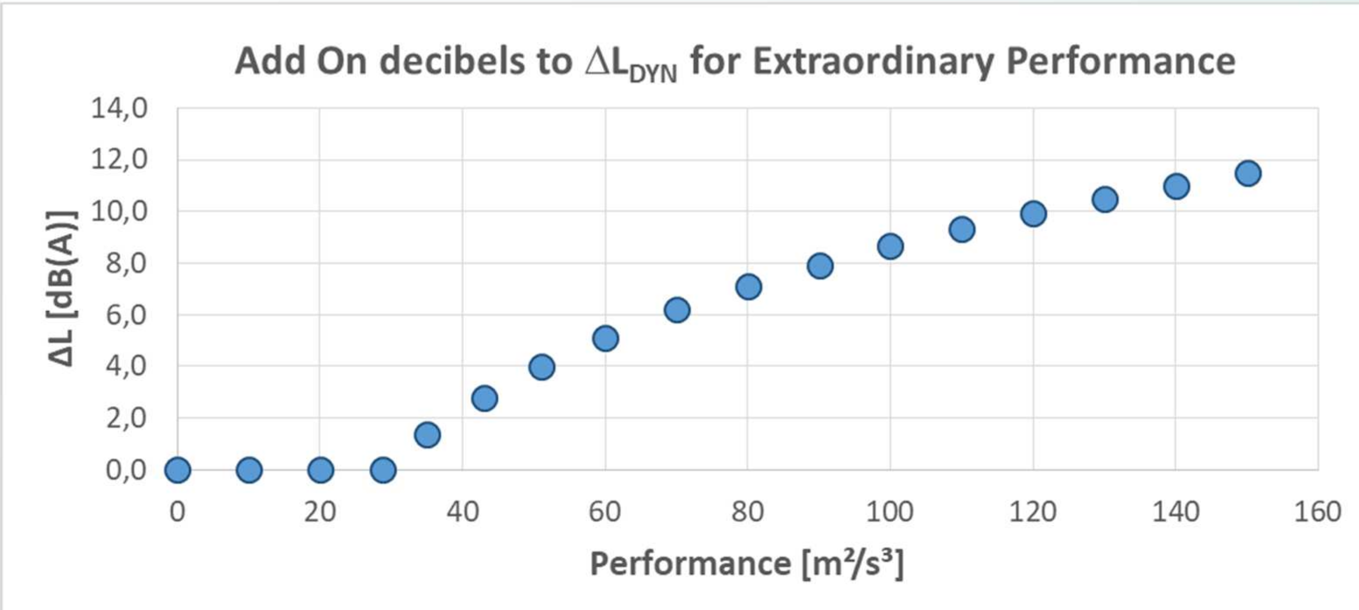
$$\Delta L_{DYN(va)} = \beta * \log(va_{test} / va_{ref})^2 \qquad \text{with } \beta \text{ as a adjustable factor}$$

- For the actual model, the factor $\beta$ was set to 8.
- The total dynamic of the vehicle is the set to:

$$\Delta L_{DYN(tot)} = \Delta L_{DYN} + \Delta L_{DYN(va)}$$

- The total dynamic $\Delta L_{DYN(tot)}$ is subject to the partial load model.

# The Effect of the v x a in the Sound Model




| Acceleration m/s² | Vehicle Speed km/h 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| 0,5 | 1,4 | 2,8 | 4,2 | 5,6 | 6,9 | 8,3 | 9,7 | 11,1 | 12,5 | 13,9 |
| 1,0 | 2,8 | 5,6 | 8,3 | 11,1 | 13,9 | 16,7 | 19,4 | 22,2 | 25,0 | 27,8 |
| 1,5 | 4,2 | 8,3 | 12,5 | 16,7 | 20,8 | 25,0 | 29,2 | 33,3 | 37,5 | 41,7 |
| 2,0 | 5,6 | 11,1 | 16,7 | 22,2 | 27,8 | 33,3 | 38,9 | 44,4 | 50,0 | 55,6 |
| 2,5 | 6,9 | 13,9 | 20,8 | 27,8 | 34,7 | 41,7 | 48,6 | 55,6 | 62,5 | 69,4 |
| 3,0 | 8,3 | 16,7 | 25,0 | 33,3 | 41,7 | 50,0 | 58,3 | 66,7 | 75,0 | 83,3 |
| 3,5 | 9,7 | 19,4 | 29,2 | 38,9 | 48,6 | 58,3 | 68,1 | 77,8 | 87,5 | 97,2 |
| 4,0 | 11,1 | 22,2 | 33,3 | 44,4 | 55,6 | 66,7 | 77,8 | 88,9 | 100,0 | 111,1 |
| 4,5 | 12,5 | 25,0 | 37,5 | 50,0 | 62,5 | 75,0 | 87,5 | 100,0 | 112,5 | 125,0 |
| 5,0 | 13,9 | 27,8 | 41,7 | 55,6 | 69,4 | 83,3 | 97,2 | 111,1 | 125,0 | 138,9 |

The Add On is only applied, when the vehicle truely provides this performance.

E.g. under crusing or almost crusing and under coast-down, nothing is added.

For a performance of 100 m²/s³ at 80 km/h an acceleration of 4,5 m/s² is needed.