ELECTRIC BUSES AND NOISE

By Janos Turcsany, Features&NVH, CD74110
Topics

• What is the difference between an electric bus and a diesel bus from a noise point of view?
  – Exterior Noise
  – Interior Noise
  – Indoor noise

• What are the benefits of quiet buses?
  – Health effects
  – Does noise cost anything?

• Are electric vehicles too quiet?

• Added noise - AVAS

• Do our electric and hybrid buses need it?

• Can we make our buses even quieter?

• What do we communicate externally?
What is the difference between an electric bus and a diesel bus from a noise point of view?

Exterior and interior noise  

**Exterior Noise**  
*Pass-By: Used for certification of noise level, is what the customer see.*  
*Cruise-by: Noise measurement of constant speeds*  
*Take-off: Is what is heard when standing at a bus stop.*

**Interior Noise**  
• *Noise level when idling: Important for tenders*  
• *Constant speeds: Important for tenders*
Exterior noise
Exterior Cruise-By Noise

Both vehicles run in electric mode.

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<thead>
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<th>Speeds (Kph)</th>
<th>Diesel City bus</th>
<th>Hybrid City bus</th>
<th>Electric City bus</th>
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SPL (dBA)
Exterior Take-Off Noise

SPL (dBA)

60
65
70
75
80

Diesel
Intercity bus

Electric
City bus

6 dBA Difference
Exterior Noise Low Idle (7m from bus side)

Background noise: Noise level is set by environmental noises, like birds singing.
Interior Noise
Interior Idling And Constant Speeds

<table>
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<th>Speed (Kph)</th>
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<tr>
<td>80</td>
<td>Citybus in electric mode</td>
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</table>

- Diff. 0dBA
- Diff. 6dBA
- Diff. 10dBA

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Interior Idling And Constant Speeds Loudness* Level

*Loudness is the characteristic of a sound that is psychologically correlated to physical strength (amplitude).

- Citybus in diesel mode
- Citybus in electric mode

- 0 Speed (Kph)
- 50 Speed (Kph)
- 80 Speed (Kph)
Indoor noise level prediction - method

• When you want to predict the noise level in an apartment, you need to know the noise level outdoors, at the facade. You also need to know the noise reducing properties (insertion loss) of the partition wall (the facade). We are here neglecting the influence of the reverberation time in the apartment.

• When all the above properties are known, the following formula applies.

\[
\text{Noise Level Outdoors} - \text{Insertion loss of facade} = \text{Noise level indoors}
\]
Indoor noise level prediction - calculation

- Sound insulation of a façade is set by the weakest point, normally the window.

![Noise reduction 3-glas window graph](image)

**Noise reduction 3-glas window**

- Frequency (Hz)
- Noise reduction (dB)

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13 2016-02-01

Volvo Buses. Driving quality of life
Indoor noise level prediction

Simplified:

Noise level outdoors – Noise attenuation of window = Noise level indoors*

*No consideration is taken to room resonances. If that would have been considered then the noise level difference would increase.

Noise Level Outdoors – Insertion loss of facade = Noise level indoors

Electric
67 dBA

Diesel
74 dBA

Electric
31 dBA

Diesel
46 dBA

The above calculation is made in the frequency plane.
What are the benefits of quiet buses?
Health effects

- About 120 million people in the EU (more than 30% of the total population) are exposed to unhealthy noise levels.
- Disability-adjusted life years (DALY)
  - Sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.
  - 10 000 premature deaths per year

Estimate of DALY's from different environmental aspects

- Noise exposure (sound level)
  - Direct pathway
  - Indirect pathway
    - Hearing loss
      - Disturbance of activities, sleep communication
      - Cognitive and emotional response
    - Stress indicators
      - Physiological stress reactions
        - Autonomic nervous system (sympathetic nerve)
        - Endocrine system (pituitary gland, adrenal gland)
      - Risk factors
        - Blood pressure
        - Blood lipids
        - Blood viscosity
        - Cardiac output
        - Blood glucose
        - Blood clotting factors
      - Manifest disorders
        - Cardiovascular diseases
          - Hypertension
          - Arteriosclerosis
          - Ischaemic heart diseases
Health effects

It is estimated that DALYs lost from environmental noise in the western European countries are:

• 61 000 years for ischaemic heart disease
• 45 000 years for cognitive impairment of children
• 903 000 years for sleep disturbance
• 22 000 years for tinnitus
• 654 000 years for annoyance

If all of these are considered together, the range of burden would be 1.0–1.6 million DALYs.

This means that at least 1 million healthy life years are lost every year from traffic-related noise in the western European countries, including the EU Member States.

Sleep disturbance and annoyance related to road traffic noise constitute most of the burden of environmental noise in western Europe.

Does noise cost anything?

Socio-economic cost

It includes:
- Effect on real estate cost
- Flexibility of usage
- Includes some health effect costs for long term noise exposure. Mainly cardiovascular diseases and high blood pressure. These lead to increase costs for health.

It does not include:
- Noise affecting people on the street
- Noise affecting people at work and in schools
- Noise attenuating measures
- Noise affecting bus drivers and passengers
- Loss in sales for shops in noisy less attractive neighborhood.
- Costs due city densification hurdles.
- Difficulties for collective traffic flexibility.

Ref. Koucky&Partners 2014

Normally, the effect of noise peaks are not included, which if included could have a significant influence on the socio-economic cost. WSP (2007)
Does noise cost anything?

Volvo/KPMG analysis finds cities could save millions with electric buses instead of diesel
26 September 2015

A city with half a million inhabitants would save about **SEK 100 million** (US$12 million) per year if the city’s buses ran on electricity instead of diesel, according to an analysis conducted in collaboration between the Volvo Group and the audit and advisory firm KPMG. The analysis has taken into consideration such factors as noise, travel time, emissions, energy use, taxes and the use of natural resources.

_Standard investment appraisals do not take into account all of the costs that impact society and the environment. Therefore, to quantify all of the aspects, we have now calculated the monetary value of an electric bus line. The results show that irrespective of the number of parameters taken into consideration, electric buses comprise the leading public transport solution._

— Niklas Gustafsson, Head of Sustainability at the Volvo Group

The analysis was based on a city with about half a million inhabitants and 400 buses. If the buses were run on electricity instead of diesel, the total annualized societal saving would be about SEK 100 million. Among other areas, the savings stem from reduced noise and air pollution, which is estimated to lead to decreased care costs of up to SEK 24 million (US$2.9 million). The annual reduction in carbon dioxide emissions would total 33,000 tons, corresponding to about 3,000 Swedish households.
Does noise cost anything?

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<th>Total kostnad för störning från utomhus- och inomhusbuller</th>
<th>Kostnad för störning från buller utomhus</th>
<th>Kostnad för störning från buller inomhus</th>
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Cost for noise disturbance from roadnoise, including costs for adverse health effects. **Total cost per person and year** for both outdoor and indoor noise and also cost per person and year for only outdoor and indoor noise respectively. The noise level indoors are assumed to be the outdoor noise level at the facade minus a facade insulation of 27dBA. Costs per person and year according to 2010 year monetary value. ([Trafikverket, Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 5.2, kap 10](#))
Are electric vehicles too quiet?
Are electric vehicles too quiet?

• According to the European Parliament, electric vehicles can be dangerous for blind and visually impaired.

• In the future electric and hybrid vehicles needs to be modified to achieve a minimum noise level.

• This will be a legal requirement from 2019 for all new hybrid and electric vehicles, and for all registered hybrid and electric vehicles from 2021.

• Some manufacturer of electric vehicles have already added atrifical sounds to their vehicles. Renault ZOE sounds

• A common standardized way of defining an added sound is under construction within the UN – It will be called AVAS (Acoustic Vehicle Alerting System)
Minimum sound from EV/HEV - QRTV

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AVAS (Acoustic Vehicle Alerting System)
Acoustic Vehicle Alerting System (AVAS) Manufacturers shall install AVAS meeting the requirements set out in Annex VIII in new types of hybrid electric and pure electric vehicles by 1 July 2019. Manufacturers shall install AVAS in all new hybrid electric and pure electric vehicles by 1 July 2021. Before those dates, where manufacturers choose to install AVAS in vehicles, they shall ensure that those AVAS comply with the requirements set out in Annex VIII. The Commission shall be empowered to adopt delegated acts in accordance with Article 10 in order to review Annex VIII and to include more detailed requirements on the performance of AVAS or of active safety systems, taking into account the UNECE work on that issue, by 1 July 2017.
EU 540/2014

ANNEX VIII

MEASURES CONCERNING THE ACOUSTIC VEHICLE ALERTING SYSTEM (AVAS)

This Annex sets out measures concerning the Acoustic Vehicle Alerting System (AVAS) for hybrid electric and pure electric vehicles.

AVAS

1. **System performance** If AVAS is installed on a vehicle, it shall comply with the requirements referred to below.

2. **Operation conditions** (a) **Sound generation method:** The AVAS shall automatically generate a sound in the minimum range of vehicle speed from start up to approximately 20 km/h and during reversing. Where the vehicle is equipped with an internal combustion engine that is in operation within the vehicle speed range defined above, the AVAS shall not generate a sound. For vehicles having a reversing sound warning device, it is not necessary for the AVAS to generate a sound whilst reversing. (b) **Switch:** The AVAS shall be fitted with a switch which is easily accessible by the vehicle driver in order to allow engaging and disengaging. Upon restarting the vehicle, AVAS shall default to the switched on position. (c) **Attenuation:** The AVAS sound level may be attenuated during periods of vehicle operation.

3. **Sound type and volume** (a) The sound to be generated by the AVAS shall be a continuous sound that provides information to the pedestrians and other road users of a vehicle in operation. The sound should be easily indicative of vehicle behavior and should sound similar to the sound of a vehicle of the same category equipped with an internal combustion engine. (b) The sound to be generated by the AVAS shall be easily indicative of vehicle behavior, for example, through the automatic variation of sound level or characteristics in synchronization with vehicle speed. (c) The sound level generated by the AVAS shall not exceed the approximate sound level of a vehicle of the M1 category equipped with an internal combustion engine and operating under the same conditions.
6.2. Acoustics characteristics

The sound emitted by the vehicle type submitted for approval shall be measured by the methods described in Annex 3 to this Regulation.

If the vehicle that is not equipped with an AVAS fulfils the overall levels as specified in table 2 below with a margin of +3 dB(A), the specification for one-third octave bands and the frequency shift do not apply.

6.2.1 Constant speed tests

6.2.1.1 The speed range for constant speed tests is the range of greater 0 km/h up to and inclusive 20 km/h.

6.2.1.2 The test speeds for approval are 10 km/h and 20 km/h.

6.2.1.3 When tested under the conditions of Annex 3 paragraph 3.3.2, the vehicle shall emit a sound

- that has a minimum overall sound pressure level for the applicable test speed according to Table 2 of paragraph 6.2.8.

- that has at least two of the one-third octave bands according to Table 2 of paragraph 6.2.8. At least one of these bands shall be below or within the 1600 Hz one-third octave band.

- with minimum sound pressure levels in the chosen bands for the applicable test speed according to Table 2 of paragraph column 3 or column 4.

6.2.3. Frequency shift to signify acceleration and deceleration

The intention of frequency shift is to acoustically inform road users about the change in vehicle speed

6.2.3.1 When tested under the conditions of Annex 3 paragraph 4., at least one tone within the frequency range as specified in paragraph 6.2.9. emitted by the vehicle shall vary proportionally with speed within each individual gear ratio by an average of at least 0.8% per 1 km/h in the speed range from 5 km/h to 20 km/h inclusive when driving in forward direction. In case that more than one frequency is shifted, only one frequency shift needs to fulfil the requirements.
Table 2: Minimum Sound Level Requirements in dB(A)

<table>
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<tr>
<th>Frequency in Hz</th>
<th>Overall</th>
<th>Column 3</th>
<th>Column 4</th>
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Sound Type and Volume

The sound to be generated by the AVAS should be a continuous sound that provides information to the pedestrians and vulnerable road users of a vehicle in operation.

However, the following and similar types of sounds are not acceptable:
- Siren, horn, chime, bell and emergency vehicle sounds
- Alarm sounds e.g. fire, theft, smoke alarms
- Intermittent sound

The following and similar types of sounds should be avoided:
- Melodious sounds, animal and insect sounds
- Sounds that confuse the identification of a vehicle and/or its operation (e.g. acceleration, deceleration etc.)

The sound to be generated by the AVAS should be easily indicative of vehicle behavior, for example, through the automatic variation of sound level or characteristics in synchronization with vehicle speed.

The sound level to be generated by the AVAS should not exceed the approximate sound level of a similar vehicle of the same category equipped with an internal combustion engine and operating under the same conditions.

Environmental consideration:

The development of the AVAS shall give consideration to the overall community noise impact.
Does our electric and hybrid buses need AVAS?

The answer is NO, we fulfill the future requirement already today. Our vehicle does not require additional noise, it is considered as safe as it is.
Summary