

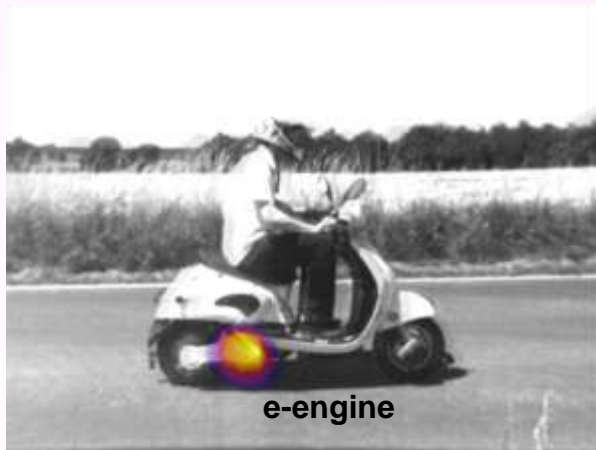
Scooters: Noise of electric and combustion powered scooters. PTW noise levels, resulting annoyance and potential for reduction

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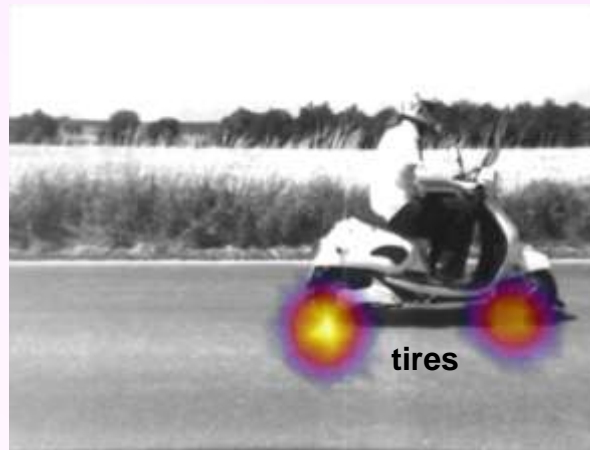
Motivation

- Since in southern European cities powered-two wheelers are widely spread, this noise source require particular attention
- Especially in the context of preserving and creating quiet zones this noise is of particular importance
- E.g. Bologna: Up to **20%** of everyday life movements are performed by motorbike or moped (Paviotti, 2011)
- Even in Germany over **3.8 Mio** powered two-wheelers (PTW) are registered with tendency to rise

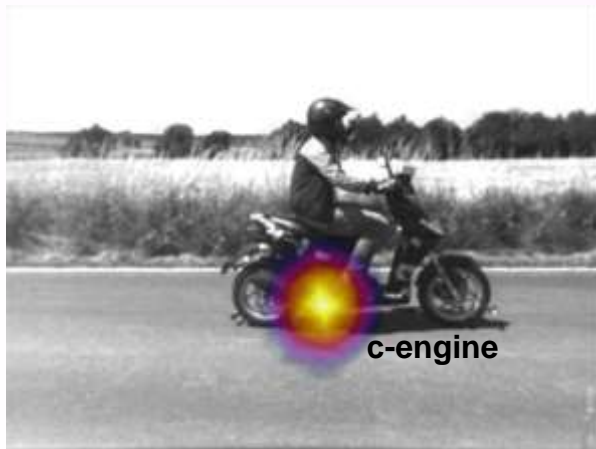
Identification of Relevant Noise Sources



E-Scooter



E-Scooter



C-Scooter



C-Scooter

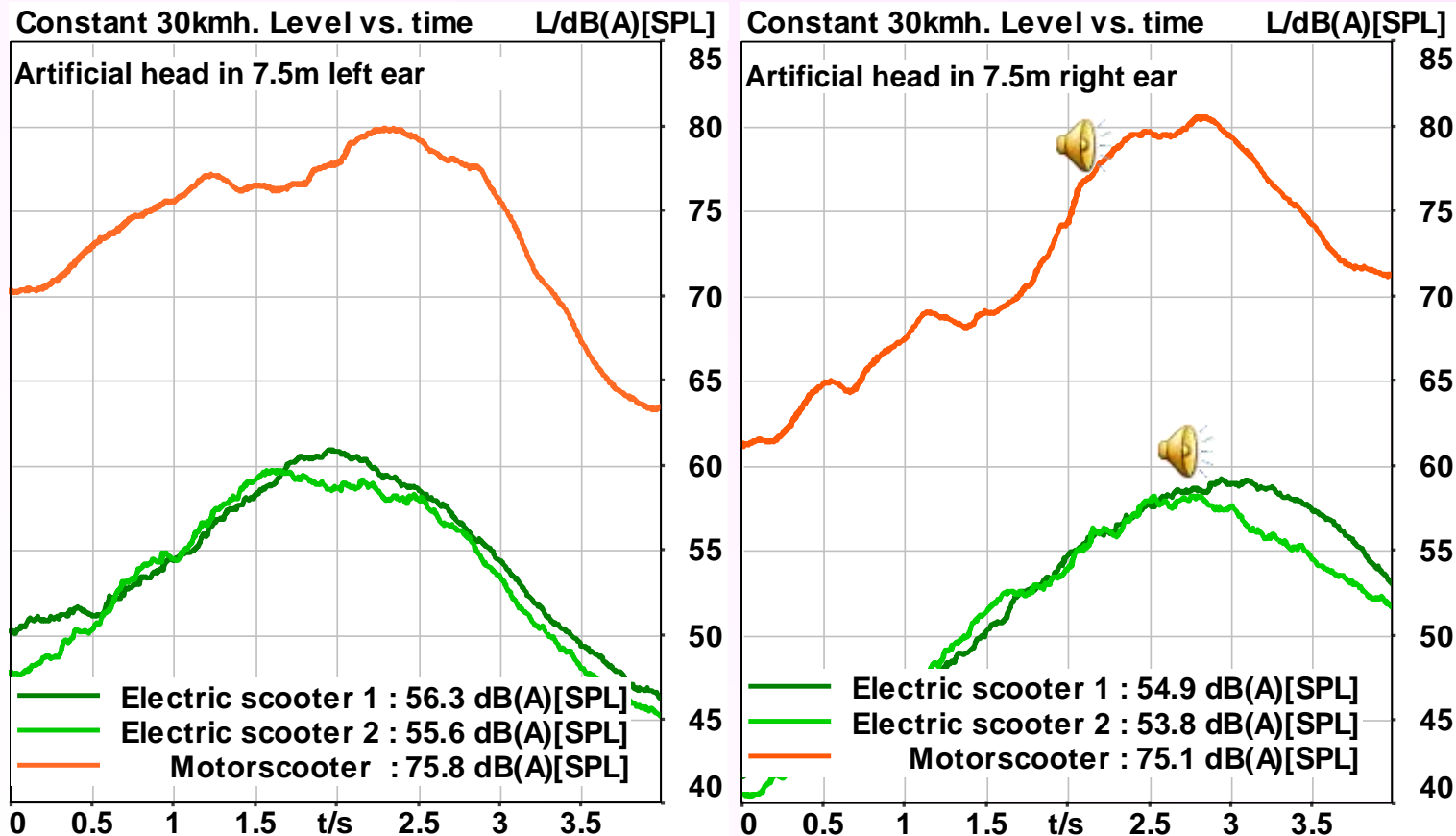
- Use of *microphone array* for detection of most relevant noise sources
- The detected sources must be considered in simulation

How Loud are (Electric) Motorbikes?



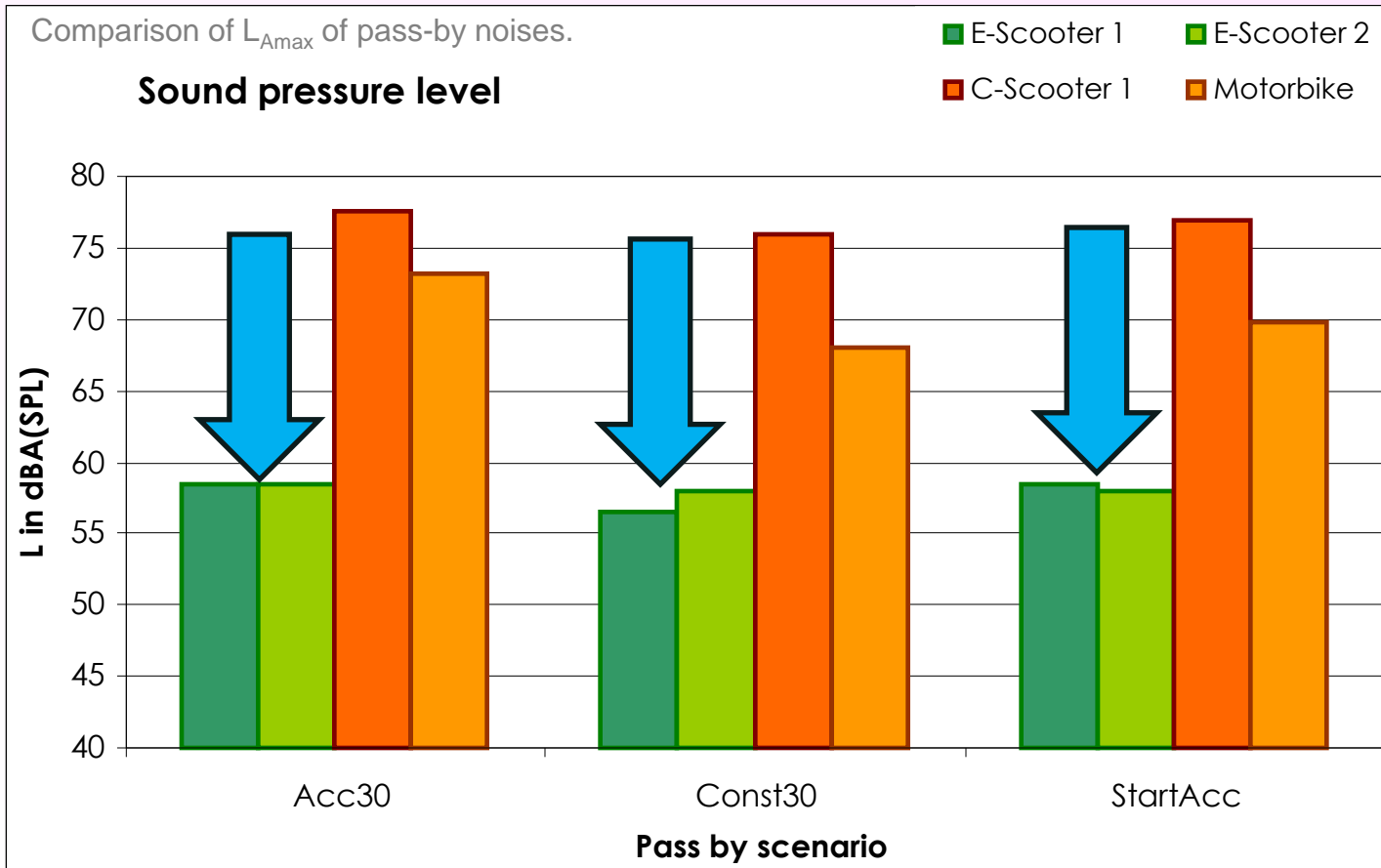
- Pass-by measurements according to ISO 362 and ISO 9645
- Pass-by measurements regarding typical urban driving conditions (starting, low constant speed)

Noise Reduction Potential of Scooters



- Electrification of scooters will be highly effective (up to 20 dB difference)

Comparison of the L_{Amax} of Scooters for 3 Pass-by Scenarios



- Up to 18 to 20 dB lower L_{Amax} of E-Scooter compared to C-Scooter
- Motorbike shows lower L_{Amax} than C-Scooter

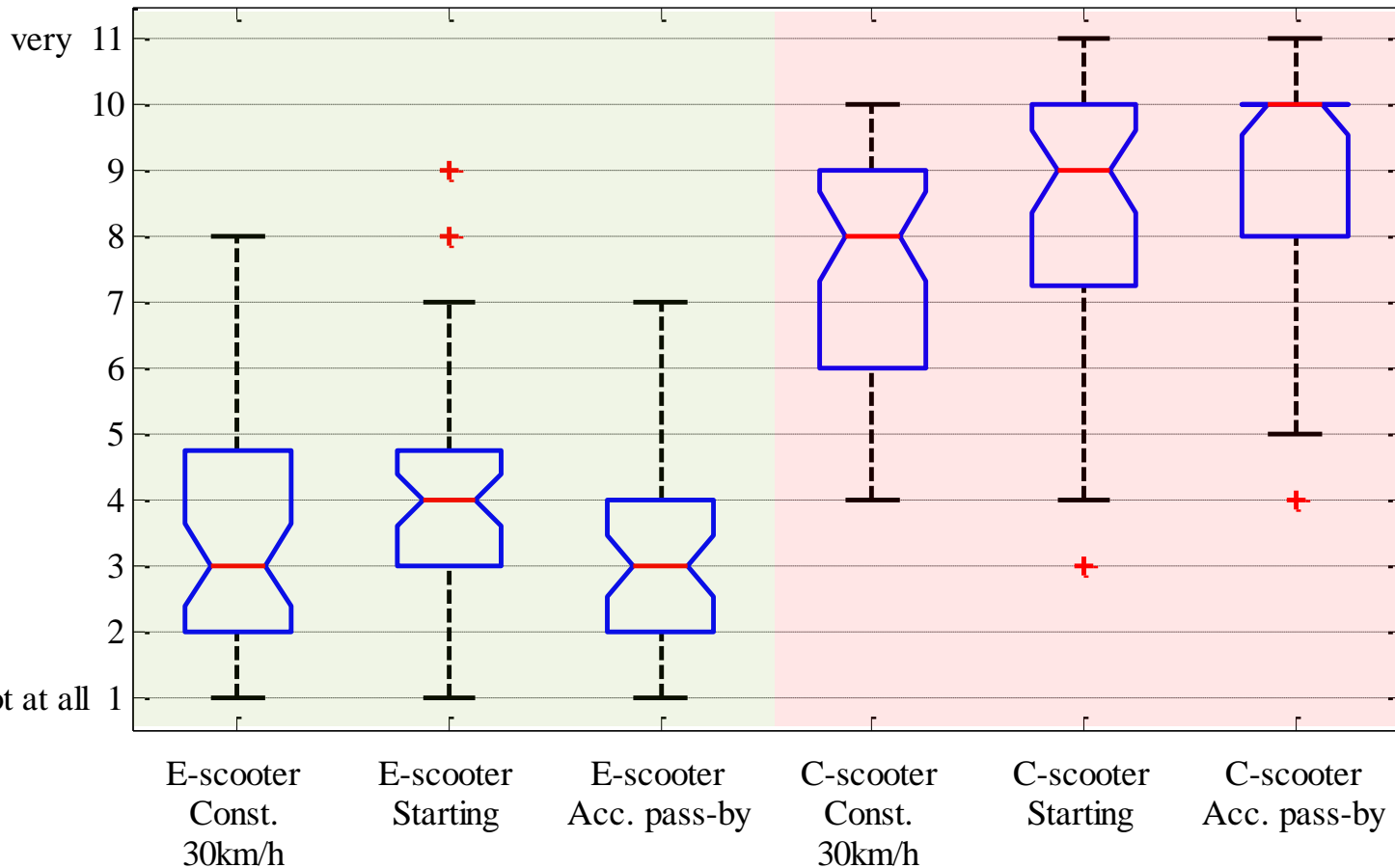
Performance of Listening Tests

- For the investigation of PTW noise and for the validation of the predicted annoyance caused by PTWs diverse listening tests in the laboratory were carried out



Annoyance of Single Pass-by Noise Events

Judged annoyance of scooter pass-by noise

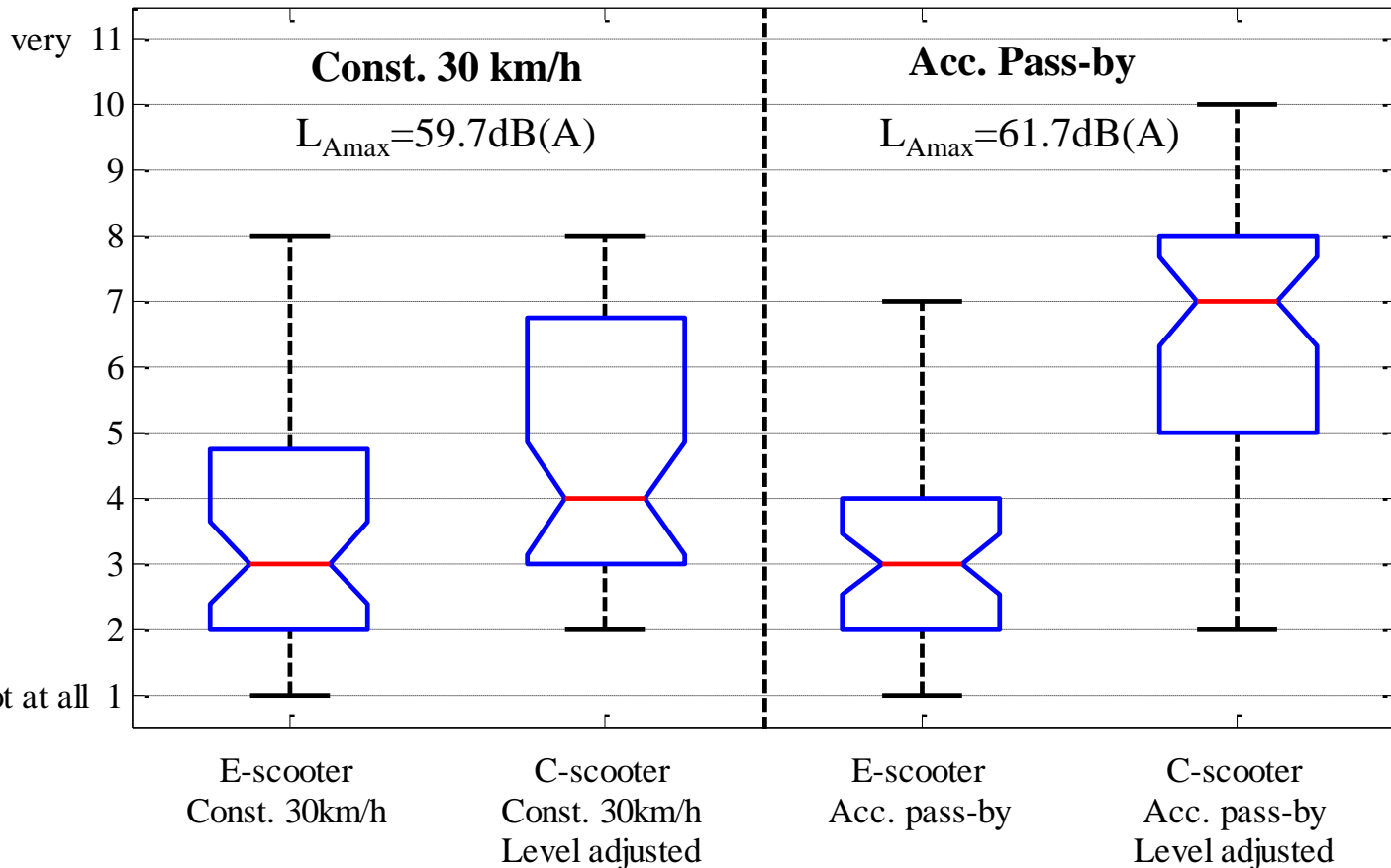


Box-and-whisker plot: Annoyance ratings of different scooter pass-by scenarios

- Annoyance of C-Scooters is significantly higher than the annoyance of E-Scooter pass-by noise
- In all driving conditions this significant difference exists

Is it only a Question of Sound Pressure Level?

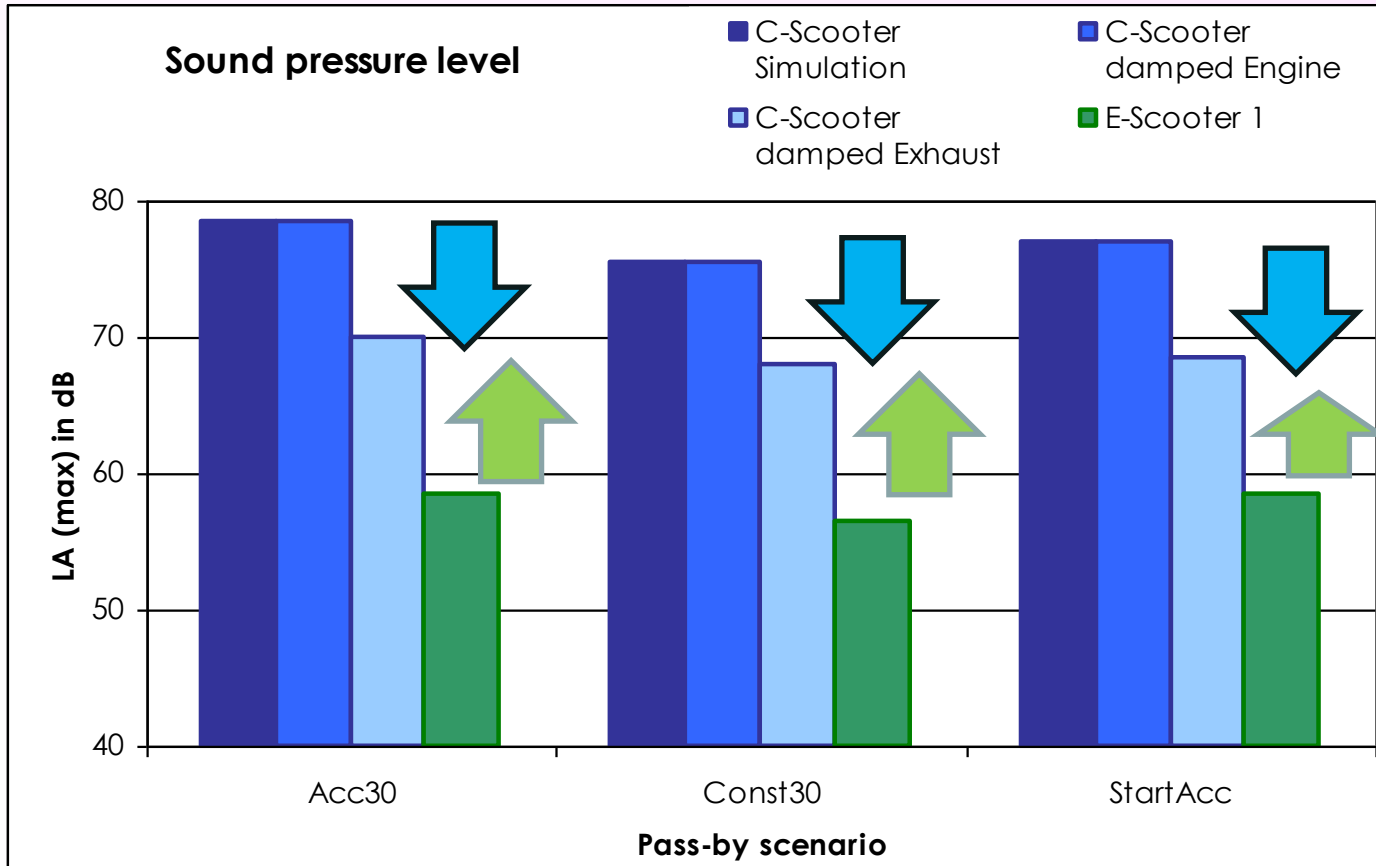
Judged annoyance of scooter pass-by noise



Box-plot: C-scooter noise is adjusted to E-scooter in sound pressure level (L_{Amax})

- High annoyance potential of C-scooters caused by psycho-acoustic properties beyond SPL (e.g. high roughness)

Comparison of L_{Amax} of Virtual Damping Modifications

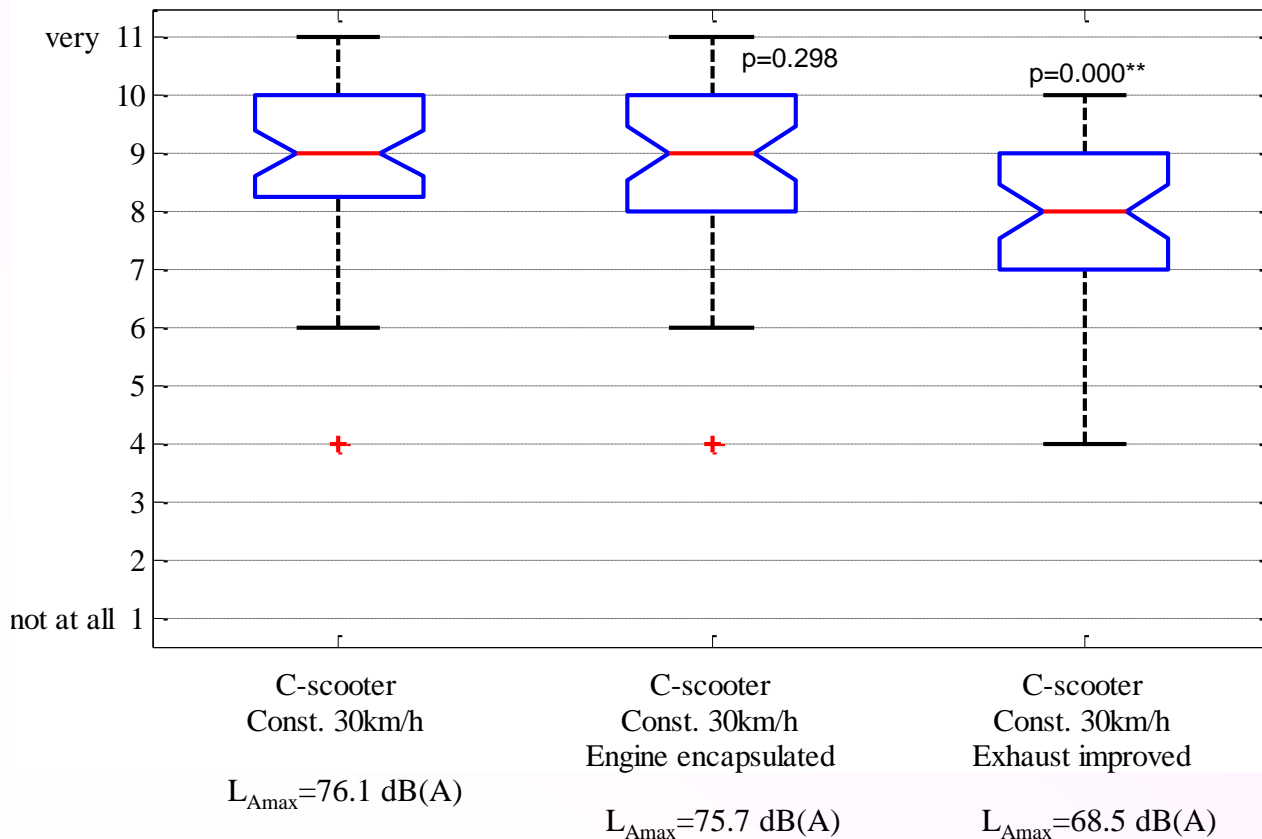


Comparison of L_{Amax} of pass by noises with respect to virtual damping modifications. All scenarios are simulated with TNS

- C-Scooter with modified engine shows almost no difference
- The modification of the exhaust radiation results in a significant reduction in SPL
- Although there is a level reduction due to the modified exhaust, the SPL of the E-Scooter is still considerable lower

Annoyance of Single Pass-by Noise Events - Modified

Judged annoyance of scooter pass-by noise



Box-and-whisker plot:
Annoyance ratings of
different (modified)
scooter pass-by scenarios

- Annoyance reduction effect due to the damping of the combustion engine can be neglected
- The damping of the exhaust system leads to a reduction of perceived annoyance of only one category (by -8 dB noise reduction)

Conclusion I: Evaluation of Single Pass-by Noise of PTWs

- A great noise reduction can be achieved when combustion engine powered scooters would be replaced by electric ones
- This is particularly effective concerning scooters with small twin-stroke engines
- Even considerable modifications at major sources of C-scooters do not lead to a significant noise annoyance reduction

Powered Two-Wheelers and Their Acoustical and Perceptual Impact on **Road Traffic**



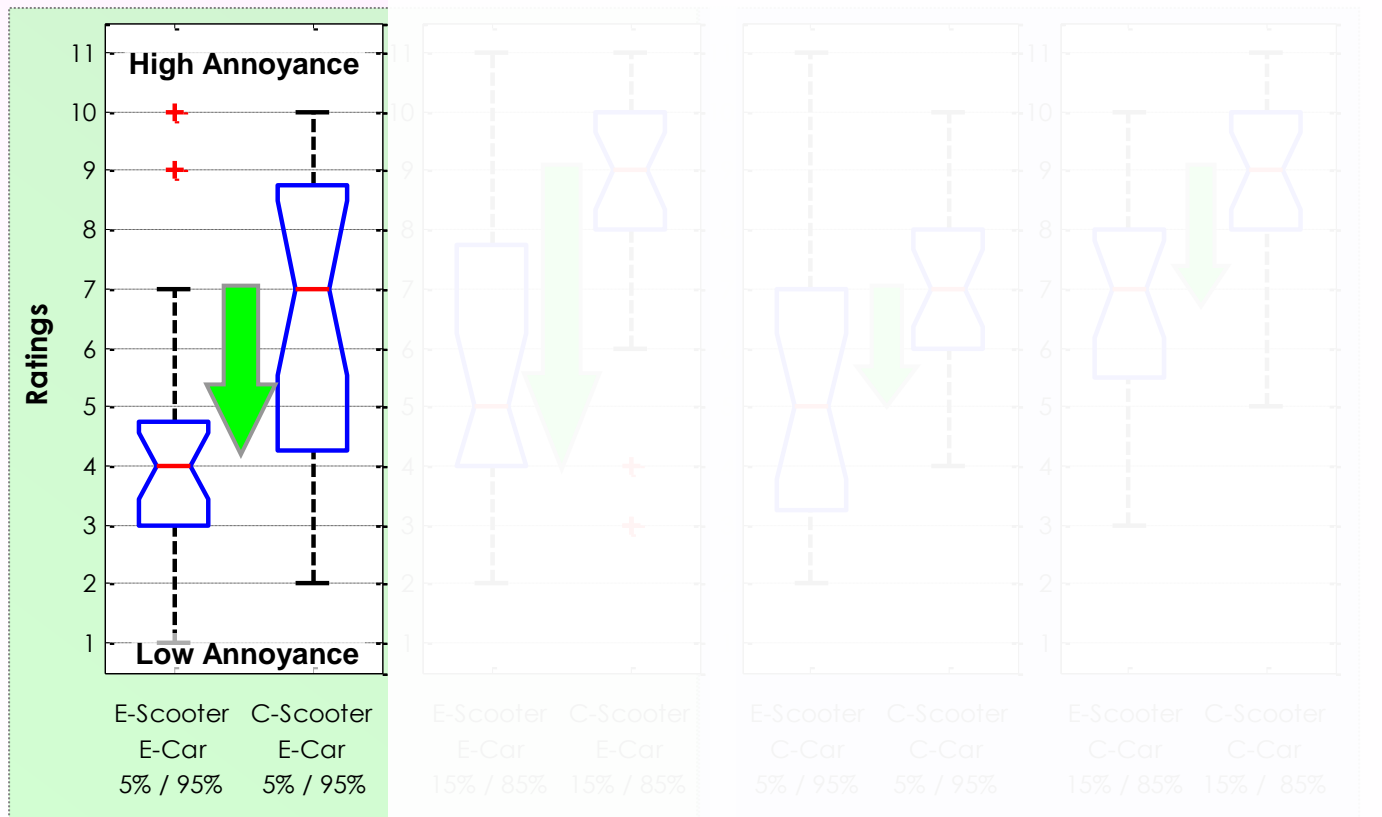
<http://shanghai.talkmagazines.cn/issue/2012-02/hanoi-city-verge>

Generation of Road Traffic Flows Including PTWs

- Scooter noise is evaluated in the context of complete road traffic scenarios (use of **Traffic Noise Synthesizer** technology)
- Two different shares of E- and C-Scooters with respect to the total traffic flow were simulated: **5 %** and **15 %**
- The passenger car traffic flow is simulated as **C-Cars (ICE)** and **E-Cars (EV)** with a speed limit of 30 km/h and 1440 vhp

Annoyance of Different Road Traffic Scenarios

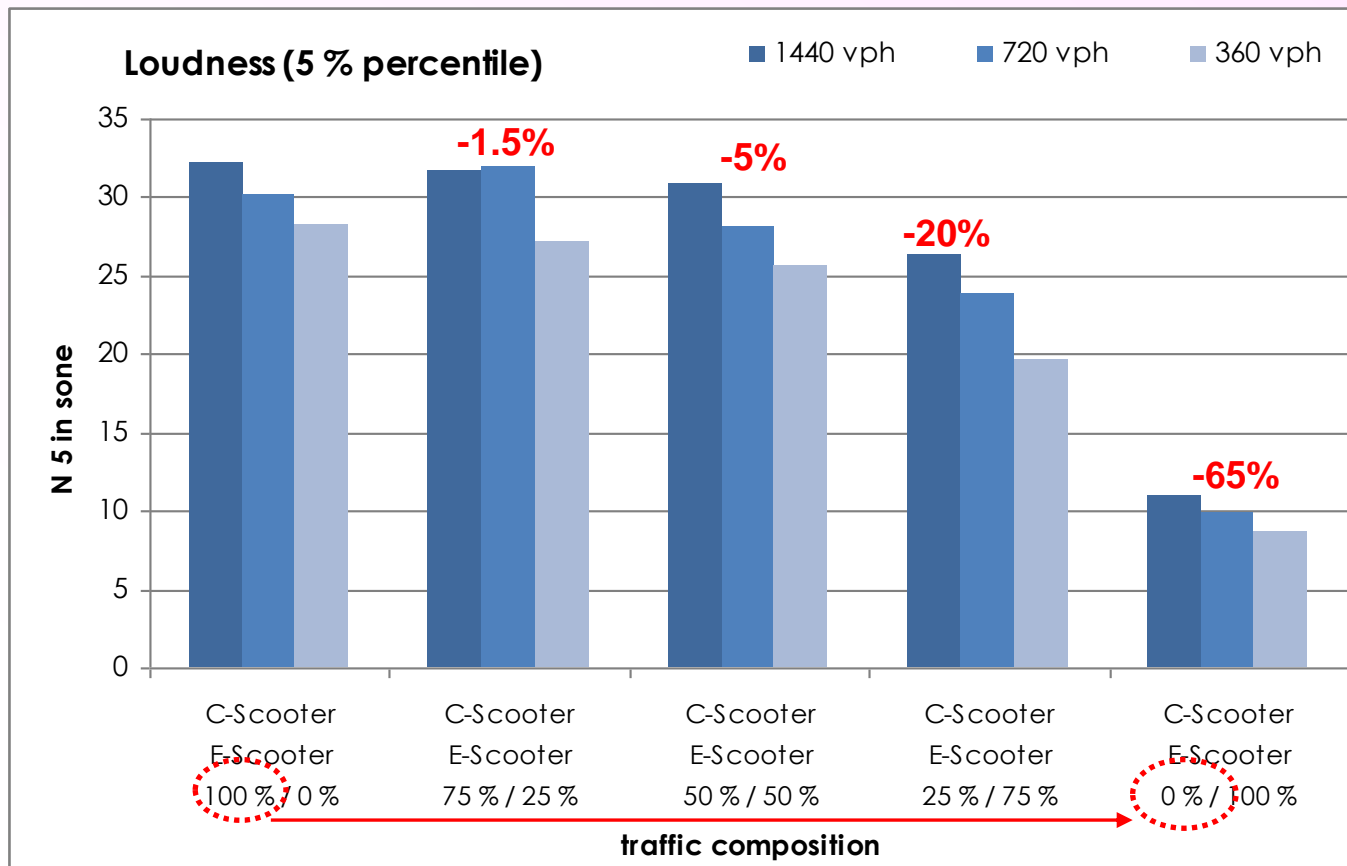
Annoyance of traffic scenario



Change from E- to C-Scooter while the surrounding traffic scenario is kept (720 vph)

Evaluation of Pure Scooter Traffic

Variation of scooter composition (share of E-Scooters changed from 0% to 100%)



Comparison of N_5 -values for different compositions of C- and E-Scooters for different traffic volumes

- Loudness can only be reduced significantly, if the C-Scooter share is reduced to a minimum close to zero

Summary



Final Remarks and Summary

- Road traffic with a certain share of C-scooters is always perceived as more annoying independent from surrounding passenger car traffic.
- This annoyance trend is even more significant, when the surrounding traffic consists of electric.
- The improvement when introducing electric cars remains low when scooters with combustion engines are still present



Only a restrictive policy against powered two wheelers equipped with combustion engines is an efficient solution for Q-Zones!

Thank you for your attention!



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