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

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CityHush Training Workshop
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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

- 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)
- Electrification of scooters will be highly effective (up to 20 dB difference)
Comparison of the $L_{A\text{max}}$ of Scooters for 3 Pass-by Scenarios

- Up to 18 to 20 dB lower $L_{A\text{max}}$ of E-Scooter compared to C-Scooter
- Motorbike shows lower $L_{A\text{max}}$ 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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Annoyance Ratings</th>
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<tbody>
<tr>
<td>E-scooter Const. 30km/h</td>
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<td>E-scooter Starting</td>
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<td>E-scooter Acc. pass-by</td>
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<td>C-scooter Const. 30km/h</td>
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<td>C-scooter Starting</td>
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<td>C-scooter Acc. pass-by</td>
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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?

<table>
<thead>
<tr>
<th>Judgment of Scooter Pass-by Noise</th>
<th>Const. 30 km/h</th>
<th>Acc. Pass-by</th>
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<td>E-scooter Const. 30 km/h</td>
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<td>C-scooter Const. 30 km/h</td>
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Box-plot: C-scooter noise is adjusted to E-scooter in sound pressure level ($L_{A_{max}}$)

- High annoyance potential of C-scooters caused by psycho-acoustic properties beyond SPL (e.g. high roughness)
Comparison of $L_{A\text{max}}$ of Virtual Damping Modifications

- 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 considerably lower
Annoyance of Single Pass-by Noise Events - Modified

- 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)

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

- C-scooter Const. 30km/h
  - $L_{A_{\text{max}}} = 76.1$ dB(A)
- C-scooter Const. 30km/h Engine encapsulated
  - $L_{A_{\text{max}}} = 75.7$ dB(A)
- C-scooter Const. 30km/h Exhaust improved
  - $L_{A_{\text{max}}} = 68.5$ dB(A)

Stockholm, December 11, 2012
Fiebig: Annoyance of Powered-Two Wheelers
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 N5-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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