Acoustic materials and spaces for sustainability

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Outline

1. Acoustics and sustainability: overview
2. Lifecycle analysis on common acoustic materials
   - Room acoustic materials: Ecopoints
   - Noise barrier materials: LCA
3. Acoustic spaces: comfort and social sustainability
I. Acoustics and sustainability: overview
Noise in High Density Urban Environment

- Some urban structures are more noise-resistant.

Self-noise-protection - buildings
Noise Reduction Using Natural Means

Use vegetation for aesthetic purpose and noise reduction

In open fields, tall vegetation can cause sound reduction compared with open grassland and tree and shrub arrangements are important.

particularly efficient in an urban context – due to multiple reflections in street canyons
Some of the sustainable techniques may also bring noise problems and thus affect the overall sustainability, for example, wind farm.
Designing sustainable building envelopes often related to acoustic issues - building opening and natural ventilation.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>4mm Float Glass</td>
<td>Source Side Opening (SSO)</td>
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<tr>
<td>10 mm &quot;J&quot; Gridline</td>
<td>Receiving Side Opening (RSO)</td>
</tr>
<tr>
<td>Typical Window Width (TWW)</td>
<td>MPA (Various Layers &amp; Dimensions)</td>
</tr>
<tr>
<td>Sound Source Side &quot;Exterior&quot;</td>
<td>Minimum Ventilation Gap (MVG)</td>
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<tr>
<td>Sound Receiving Side &quot;Interior&quot;</td>
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Window systems that can reduce noise transmission, get natural ventilation and daylight.
Acoustic Materials

- Recycled acoustic materials
  - Tyres
  - Carpets
  - ...

- Various acoustic materials may have similar acoustic performances but very different characteristics in terms of sustainability.
Sound Quality in the Built Environment

- Good physical and acoustic comfort quality is important.

- In various spaces the noise control and introducing pleasant sounds are very important.
  - Sounds as resources not just waste

- Acoustic problem remedy may be expensive, inefficient and affect the sustainable development.
II. Lifecycle analysis on common acoustic materials
Introduction/ purpose

With the same acoustic performance, what is the potential for acoustics-related materials to achieve better sustainability?

Explore the methodology of carrying out life-cycle assessment, considering various situations, from external noise barriers to interior finishing.
Methodology/ outline

For residential buildings:
- using software Envest,
  for Ecopoint

For environmental noise barriers: explore
a LCA framework

C Yu. PhD Thesis, University of Sheffield, UK

## Results: buildings and envelopes

### Embodied

<table>
<thead>
<tr>
<th></th>
<th>Bungalow</th>
<th>Detached</th>
<th>Semi detached</th>
<th>Terraced</th>
<th>Apartment</th>
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<tr>
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<td>Brick</td>
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<td>Brick</td>
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<tr>
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<tr>
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<td>0.08</td>
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### Operational

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<th>Acid Deposition</th>
<th>Ozone Depletion</th>
<th>Human Toxicity Air</th>
<th>Ozone Creation</th>
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<th>Eco Toxicity Water</th>
<th>Eutrophication</th>
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<th>Minerals Extraction</th>
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<td>0.03</td>
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<tr>
<td>Total Ecopoints/m²</td>
<td>17.29</td>
<td>17.96</td>
<td>19.4</td>
<td>19.39</td>
<td>17.75</td>
<td>18.25</td>
<td>19.13</td>
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<td>1</td>
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</table>
Number of storeys [noise distribution differs]

- In terms of Embodied Ecopoints 3 storeys is the lowest, followed by 4 storeys and 2 storeys, although the differences are generally insignificant.
- In terms of operational Ecopoints, the Ecopoint increases with increasing storey number, although the increase is only within about 4%.

- Roof type [sound insulation differs]
  For embodied Ecopoints a pitched roof is generally less than a flat roof, and for operational Ecopoints, the difference between the two kinds of roof is insignificant.

- Glazing ratio [sound insulation differs]
  Compared with 10% glazing ratio, with 20% glazing ratio the embodied Ecopoint has generally slightly increased by about 3-4%, whereas the operational Ecopoint has decreased, at 8-13%.
The differences in the total Ecopoints between the six configurations is generally within about 7%, which is insignificant.

The differences between the finishing materials only are rather significant, ranging from 9 to 39, with a difference of up to 300%.

Results: typical rooms (with same acoustic performance!)

with a given reverberation time (RT) and sound transmission loss

<table>
<thead>
<tr>
<th></th>
<th>Wall</th>
<th>Floor</th>
<th>Ceiling</th>
<th>Total Ecopoints</th>
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</thead>
<tbody>
<tr>
<td>LUC1</td>
<td>wood fibre board (3)</td>
<td>terrazzo tiles (4)</td>
<td>wood panels (22)</td>
<td>458</td>
</tr>
<tr>
<td>LUC2</td>
<td>Plasterboard (4)</td>
<td>wood parquet (14)</td>
<td>gypsum tiles (1)</td>
<td>448</td>
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<tr>
<td>LUC3</td>
<td>Plaster (5)</td>
<td>carpet, thin (9)</td>
<td>medium density fibreboard (3)</td>
<td>445</td>
</tr>
<tr>
<td>LPC1</td>
<td>wood boards (3)</td>
<td>wood parquet (14)</td>
<td>wood panels (22)</td>
<td>468</td>
</tr>
<tr>
<td>LPC2</td>
<td>Plasterboard (4)</td>
<td>terrazzo tiles (4)</td>
<td>gypsum tiles (1)</td>
<td>438</td>
</tr>
<tr>
<td>LPC3</td>
<td>wood boards (3)</td>
<td>carpet, thin (9)</td>
<td>gypsum tiles (1)</td>
<td>444</td>
</tr>
</tbody>
</table>
The hypothetical noise barrier

- 1km long and 2m high.
- Aluminium, steel, pre-cast concrete, Polymethyl methacrylate (PMMA), timber and willow.
- Several variations of the materials, including recycled and non-recycled aluminium and steel.
- Same conditions of distance travelled from ‘cradle-to-gate’ - 1km.
- Absolute minimum width for each material (manufactures’ data), in terms of transmission loss, as this reflects a lowest cost option.
- The embodied CO2, energy and pollutants, relating to each material’s general lifecycle as a noise barrier, were established through the collection of industry data.
Parameters considering extraction, production, distribution, use & disposal:

- Extracted minerals (t)
- Waste to landfill (kg)
- Total primary energy (mainly fossil fuel energy) (MJ/kg)
- Carbon Dioxide to air (g)
- Sulphur Dioxide to air (g)
- Oxides of Nitrogen (g)
- Heavy metals to air (g)
- Heavy metals to water (mg)
- Particulates (g)
- Water used (l)
- Financial costs (£)
- Maintenance frequency and costs
- Transportation at all stages and its associated pollutants (distance and method)
- Inclusion of recycled materials in production
- End of life recycling potential
- Final disposal
The most unsustainable materials as the un-recycled metal

Low sustainability for the willow, due to mineral wool inner core

Relatively low impact of concrete

Timber had the lowest environmental impacts
‘Gate-to-grave’ analysis

Transportation
Maintenance
Recycling potential
Typical cost

A single index for LCA

\[
LCA = (w \times T) + (R + D + M + E)
\]

*LCA*: environmental lifecycle assessment of a noise barrier
*w*: weighting
*T*: transportation impacts
*R*: recyclability
*M*: maintenance
*D*: disposal of material un-recycled to landfill
*E*: weighted environmental impacts from ‘cradle-to-gate’
Recycling potential

- **Recycled Input**: the percentage (by mass) of recycled or waste material contained within a product.
- **Recyclability**: the percentage (by mass) of material capable of being recycled or reused at the end of the product’s useful life.
- **Currently recycled**: the percentage (by mass) currently being recycled or reused in the UK.

1 = A (least environmental impact); 2 = B; 3 = C (greatest environmental impact).

Relative potential environmental benefits afforded for each material from all aspects of recycling.
III. Acoustic spaces:

Acoustic comfort and social sustainability
Introduction

- Acoustics in ‘non-acoustic’ buildings/spaces
  - shopping mall atrium spaces, library reading rooms, football stadia, swimming spaces, churches, dining spaces, urban open public spaces, … …
- UK Code for sustainable Homes: sound insulation already in, but insufficient
- Acoustic comfort vs. acoustic standards
- Sounds: waste or resources?
Library reading rooms

The SPL attenuation with distance is considerable, the RT is rather short, and the general background noise is not high.

BUT: the acoustic comfort is only at a medium or less satisfactory level, and there is no correlation between the sound level and acoustic comfort evaluation.

Showing: contradiction in designing the acoustic environment in such spaces - balance between privacy and annoyance.
Four sounds were played as background

- Rain/wind; rain; water; ventilation
- Average SPL of 50dBA
- Each sound 30 minutes for evaluation
- 40 students involved

Evaluation scores for the running water higher than others
- Weak low frequency components
- Small dynamic range
- Natural feature? - ventilation noise caused headache
The McAlpine Stadium, Huddersfield; Ewen Fields, Hyde; Valley Parade, Bradford; Edgeley Park, Stockport; Pride Park, Derby; and Maine Road, Manchester. The measured average SPL was 77-98dBA, and the maximum SPL was 102-120dBA.

The responses to two questions regarding quality of atmosphere and loudness of the stadium were very similar. Most fans do think that the atmosphere is very, if not totally, dependent on sound volume.

Fans wanted to hear sounds from the pitch better than they could – mostly by about one point on the scale.
1, Very quiet (very comfortable); 2, quiet (comfortable); 3, neither quiet (comfortable) nor noisy (uncomfortable); 4, noisy (uncomfortable); 5, very noisy (very uncomfortable).
Sounds: as waste or resources?
**Green buildings/ environments and acoustic comfort**

- Green buildings often have hard surfaces, causing long reverberation, and thus less acoustic comfort.
- Green buildings often have acoustic openings for ventilation, causing bad sound insulation, thus increasing indoor noise levels – less acoustic comfort.
Conclusions

Acoustics and sustainability are closely related in many ways, for example

1. With the same acoustic performance, the sustainability performance could vary significantly.
2. Social sustainability relating to acoustic comfort must be taken into account too. Sounds are resources not just waste...
Acknowledgements

Researchers in the team from their contributions, especially Drs. C Yu and J Joynt.