The Importance of Acoustics
A new challenge in an urban world
The Importance of Acoustics

Global Trends Towards Urbanization

Source: World Urbanization Prospects 2018, Department of Economic and Social Affairs, United Nations
Population residence in the United States urban areas increased from 190 million to 268 million over the past 30 years.

- In 2050, there will be 301 million people living in the US urban areas.

Source: World Urbanization Prospects 2018, Department of Economic and Social Affairs, United Nations
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NYC New Housing Supply

New construction, substantial rehabilitation of deteriorated buildings, and commercial to residential conversion brings the growth of new housing supplies.

- In 2017, NYC had a net total of 3,469,240 housing units.

Source: 2018 Housing Supply Report, New York City Rent Guidelines Board
New construction materials tend to be more glass and metal than brick and mortar.
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New Architectural Trends

The use of all metal and glass facades deteriorates the acoustic resilience of modern facades.

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[Graph showing the comparison of sound transmission loss for different facades]
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Health Impact

Heart Disease  
Stress  
Hypertension
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Characteristics of Sound

- Noise Level Standards
  - CEN: 30-45 dB
  - CEQR: 30-45 dB

- Noise Sources
  - Air Raid Siren
  - Rock Concert
  - Subway Train
  - Heavy Truck or Bus
  - Typical Highway
  - Automobiles with Mufflers
  - Typical Urban Area
  - Typical Suburban Area
  - Quiet Suburban Area at Night
  - Typical Rural Area at Night
  - Isolated Broadcast Studio
  - Audiometric (Hearing Testing) Booth
  - Threshold of Hearing

- Noise Perception
  - 120 dB: Pain
  - 110 dB: Scream
  - 100 dB: Loud
  - 90 dB: Moderate to Quiet
  - 60 dB: Faint
  - 0 dB: SPL (Decibels at the Ear)
The Importance of Acoustics

Higher Density = Noisier Cities

<table>
<thead>
<tr>
<th>US Road and Aviation Noise - Decibels</th>
<th>Los Angeles</th>
<th>New York</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 – 40</td>
<td></td>
<td></td>
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<tr>
<td>40 – 45</td>
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<td>45 – 50</td>
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<td>50 – 55</td>
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<td>55 – 60</td>
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<td>60 – 65</td>
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<td>65 – 70</td>
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<td>70 – 75</td>
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<td>75 – 80</td>
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<td>80 – 85</td>
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<tr>
<td>85 – 90</td>
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<td></td>
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<tr>
<td>90 – 95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: National Transportation Noise Map
A research group developed a noise calculation model to estimate the trend towards noise exposure for the inhabitants in Gothenburg, Sweden. The population increase and concentration are behind the increase of the percentage of inhabitances exposed at an equivalent noise level of 55dB.

Figure. Map of the number of persons exposed above equivalent level 55 dB per square kilometer.

Current State of Practice

How facade acoustical performance is measured
The Noise Criteria curves were first introduced at 1957 (Beranek, 1957).

- NC or “noise criteria” curves are a set of curves established by the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE)
- To classify the various levels of background noise for the design of building facilities.

<table>
<thead>
<tr>
<th>Type of Room</th>
<th>Recommended NC Level</th>
<th>Equivalent Sound Level dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Houses</td>
<td>25-35</td>
<td>35-45</td>
</tr>
<tr>
<td>Office Conference Rooms</td>
<td>25-30</td>
<td>35-40</td>
</tr>
<tr>
<td>Hospital Public Areas</td>
<td>35-40</td>
<td>45-50</td>
</tr>
<tr>
<td>School Lecture and Classrooms</td>
<td>25-30</td>
<td>35-40</td>
</tr>
<tr>
<td>Restaurants</td>
<td>40-45</td>
<td>50-55</td>
</tr>
<tr>
<td>Libraries</td>
<td>35-40</td>
<td>40-50</td>
</tr>
</tbody>
</table>
Facade systems are tested and rated at laboratory testing chambers for STC and OITC, but both ratings are outdated.

**STC: Sound Transmission Class**
- Created in 1970
- Assesses sound privacy for interior walls
- 125 Hz – 4000 Hz

**OITC: Outside-Inside-Transmission Class**
- Created in 1990
- Assesses urban sounds through exterior walls, facades, and windows
- 80 Hz – 4000 Hz

![Sound Transmission Loss Chart](chart.png)

- **STC=39**
- **OITC = 34**

Chart. A typical sound transmission loss chart for STC classification.
Using just STC or OITC does not provide enough information.

Three different glass compositions show similar behavior patterns, but their **single number rating results vary significantly.**
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Proper Criteria Setup

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Octave-band Pressure Level (dB)

Octave-band Center Frequencies (Hz)

The approximate threshold of hearing for continuous noise

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### Minimum Octave Band Transmission Loss (dB)

<table>
<thead>
<tr>
<th>Wall Types</th>
<th>63 Hz</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW-1</td>
<td>21</td>
<td>21</td>
<td>22</td>
<td>29</td>
<td>36</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>CW-2</td>
<td>21</td>
<td>23</td>
<td>23</td>
<td>34</td>
<td>38</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>CW-3</td>
<td>21</td>
<td>24</td>
<td>26</td>
<td>35</td>
<td>41</td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>CW-5</td>
<td>24</td>
<td>24</td>
<td>29</td>
<td>37</td>
<td>44</td>
<td>43</td>
<td>48</td>
</tr>
</tbody>
</table>
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**Assessment: Frame Acoustical Performance**

Glass is the major contributor to overall facade performance.

However, the contribution of framing elements become dominant when the STC rating of glass exceeds 40.

Glass and frame ratings are determined at laboratory testing facilities.
VCL had three identical compositions of glass tested at three different laboratories. Same glass, but different results!

<table>
<thead>
<tr>
<th>Lab</th>
<th>STC</th>
<th>OITC</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>C</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td>W</td>
<td>46</td>
<td>33</td>
</tr>
</tbody>
</table>
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Focus on Framing Performance

How facade acoustical performance is enhanced
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Impact of Framing on Performance

The design choices made on framing can enhance or degrade the overall acoustical performance of a facade.

- Various cavities
- Drainage and air circulation orifices
- Mechanical interlocking systems

Glass Performance & Framing Performance & Spandrel Performance
Current State of Practice
Enhancement: How to improve glass performance

Glass
- Increase glass thickness
- Apply acoustic PVB interlayer
- Choose right composition to avoid weakness at target frequencies

Frame
- Mineral wool insulation
- Double skin facade

Chart: Sound transmission loss chart for 12 mm monolithic glass
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How to improve glass performance

Glass
Acoustical PVB Interlayer

Chart. Comparison of Acoustic PVB and Regular PVB
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Enhancement: How to improve frame performance

Glass
- Increase glass thickness
- Apply acoustic PVB interlayer
- Choose right composition to avoid weakness at target frequencies

Frame
- Mineral wool insulation
- Double skin facade
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### Mineral Wool Insulation

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### The Virtual Construction Lab

#### Facade Acoustics

### Cost for Frame Enhancement

<table>
<thead>
<tr>
<th></th>
<th>IGU</th>
<th>IGU Laminated</th>
<th>Triple Layer Laminated</th>
<th>IGU Laminated + Enhanced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Glass</td>
<td>System</td>
<td>Glass</td>
<td>System</td>
</tr>
<tr>
<td>OITC</td>
<td>19</td>
<td>19</td>
<td>36</td>
<td>32</td>
</tr>
<tr>
<td>Glass Cost</td>
<td>12 $/SF</td>
<td>21 $/SF</td>
<td>55 $/SF</td>
<td>21 $/SF</td>
</tr>
<tr>
<td>Metal Cost</td>
<td>7 $/SF</td>
<td>7 $/SF</td>
<td>8 $/SF</td>
<td>7 $/SF</td>
</tr>
<tr>
<td>Enhancement Cost</td>
<td>2 $/SF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td>19 $/SF</td>
<td>28 $/SF</td>
<td>63 $/SF</td>
<td>30 $/SF</td>
</tr>
</tbody>
</table>

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Double Skin Facade

- Tempered
- Passive Absorption
- Ventilated
- Pressurized

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Double Skin Facade

Project - Columbia University Mind Behavior Center
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Pressurized Double Skin Facade

Project – Lucile Packard Children Hospital, Palo Alto California
Tools for Simulation and Prediction

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## Tools for Simulation and Prediction Technology

### Finite Element Analysis of Testing Room (FEA)

<table>
<thead>
<tr>
<th></th>
<th>F = 50 Hz</th>
<th>F = 100 Hz</th>
<th>F = 200 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acoustic Pressure</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Sound Pressure Level</strong></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

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BPS calculates acoustical performance based on existing theoretical methodology and numerous laboratory test results.

- Double layer insulated glass is determined by theoretical models.
- Frame performance is determined by field measurement data, taken from multiple testing facilities.
- Glass and frame performance are combined to get the entire window or facade STL and OITC ratings.
Understanding acoustical performance is important for engineers as well as designers and clients.

SVS, the virtual reality program developed at VCL allows users to experience the impact of acoustic design in the context of an immersive environment.

SVS utilizes real-time binaural audio to accurately simulate acoustic performance.
Tools for Simulation and Prediction

**Dynamic Auralization**

- Walk through and listen to an architectural space before it gets built.
- Reproduce subjective perception.
- Tools for demonstration and design of appropriate facade elements.
Future Trends and Products
ANC (Active Noise Cancelling) ventilation modules incorporate loudspeakers and microphones in the ventilation channel.

- The exerted noise level is recorded by the microphones.
  - The loudspeakers instantly generate a corresponding counter-noise for exterior noise level.
  - These two sound waves interfere with each other destructively to reduce the overall noise level.
Future Trends and Products

**Acoustic Metamaterial**

Incurring large phase delays within a small space.

- The space-coiling geometry forces sound waves to propagate through passages that are much longer than their external dimension.
- A phase delay is caused by the coiled-up passage.
- The structure are particularly effective for phase manipulation.

A research group from Singapore tested the acoustic performance of a metasurface ventilation window. An array of resonant-duct unit cells are used to provide superior sound reduction while offering a large opening to allow air flow through. The overall single number rating of metasurface window increased by 7dB comparing to a traditional casement window.

Future Trends and Products

Acoustic Metamaterial in Facade Engineering

Passive sound reduction through the facade promotes natural ventilation and healthier sleep.

- Air duct with soundproof metamaterials.
- Block exterior sound.
- Preserve air path to interior.
Facade design impacts building occupants and the surrounding city, including acoustic performance. Sound absorbent exterior panels would reduce the noise of city streets by making smarter choices about materials and design.
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Thank you,
let’s stay in touch.

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