Noise 101

Sources
Metrics
Noise Modeling
Federal Statutes

O’Hare Noise Compatibility Commission

June 16, 2017
WHAT IS NOISE?

• Noise is unwanted sound

• Noise is temporary

• Annoyance is subjective
How people perceive sound depends on several measurable physical characteristics of the sound:

- Intensity
- Frequency Content
- Changes in Sound Pressure Level
- Rate of Change in Level
VARIABLES AFFECTING RESPONSE

• Emotional Variables
  − Activity at the time an individual hears a noise.
  − Attitudes about the environment.
  − General sensitivity to noise.
  − Belief about the effect of noise on health.
  − Feeling of fear associated with the noise.
  − Feelings about the necessity or preventability of the noise.

• Physical Variables
  − Type of neighborhood.
  − Time of day.
  − Season.
  − Predictability of the noise.
  − Control over the noise source.
  − Length of time an individual is exposed to noise.
THE HUMAN EAR

• Most sensitive to human voice frequencies (3000 Hz)
• Decibels (dB) are the unit of measurement on the loudness scale

• The decibel scale is logarithmic, not linear
  – Two sounds of the same level are not perceived to be twice as loud
  – In fact, two sounds of the same sound level equals a 3 dB increase
1 Car = 72.0 dB
2 Cars = 144.0 dB??
2 Cars = 75.0 dB
• A-weighting most closely relates to range of the human ear
LEQ – EQUIVALENT SOUND LEVEL

Decibels Addition

Example: $80 \text{ dB} + 74 \text{ dB} = 81 \text{ dB}$

<table>
<thead>
<tr>
<th>Hour</th>
<th>dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 AM</td>
<td>40.3</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>44.7</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>38.2</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>47.6</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>41.1</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>80.4</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>55.0</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>49.5</td>
</tr>
<tr>
<td>AVERAGE Leq$_8$</td>
<td>71.4</td>
</tr>
</tbody>
</table>
Smallest detectable change by the human ear is +/- 1 dB (laboratory setting)

+/- 3 dB is noticeable to most people

Adding two like sounds adds 3 dB increase

Double or half the airport operations = +/- 3 dB on average

+/- 10 dB sounds twice as loud or twice as quiet

Double or half the distance between a sound and the receiver equates to +/- 6 dB
Comparison of Sound

**Common Outdoor Sound Levels**

- B-747-200 Takeoff*: 110 dB (A)
- Gas Lawn Mower at 3 ft.: 100 dB (A)
- Diesel Truck at 150 ft.: 90 dB (A)
- Noisy Urban Daytime B-757 Takeoff*: 80 dB (A)
- Commercial Area: 70 dB (A)
- Quiet Urban Daytime: 60 dB (A)
- Quiet Urban Nighttime: 50 dB (A)
- Quiet Suburban Nighttime: 40 dB (A)
- Quiet Rural Nighttime: 30 dB (A)
- Threshold of Hearing: 10 dB (A)

**Common Indoor Sound Levels**

- Rock Band: 110 dB (A)
- Inside Subway Train: 100 dB (A)
- Food Blender at 3 ft.: 90 dB (A)
- Garbage Disposal at 3 ft.: 80 dB (A)
- Shouting at 3 ft.: 70 dB (A)
- Vacuum Cleaner at 10 ft.: 60 dB (A)
- Normal Speech at 3 ft.: 50 dB (A)
- Large Business Office: 40 dB (A)
- Dishwasher Next Room: 30 dB (A)
- Small Theatre, Large Conference Room (Background): 20 dB (A)
- Library, Bedroom at Night, Concert Hall (Background): 10 dB (A)
- Broadcast & Recording Studio: 0 dB (A)

*As measured along the takeoff path 2 miles from the overrun end of the runway.
### Comparison of Aircraft Type

#### Sound Energy Reduction Over Time

<table>
<thead>
<tr>
<th></th>
<th>Arrival</th>
<th>Departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>727 Stage 1</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>727 Stage 2</td>
<td>-58.94%</td>
<td>-11.89%</td>
</tr>
<tr>
<td>727 Stage 3 Hushkit</td>
<td>-68.27%</td>
<td>-71.28%</td>
</tr>
<tr>
<td>727 Stage 3 Re-Engine</td>
<td>-90.15%</td>
<td>-96.32%</td>
</tr>
<tr>
<td>757 Pure Stage 3</td>
<td>-86.61%</td>
<td>-99.40%</td>
</tr>
<tr>
<td>NASA AST - 10 dB Goal</td>
<td>-98.66%</td>
<td>-99.94%</td>
</tr>
<tr>
<td>NASA AST - 20 dB Goal</td>
<td>-99.87%</td>
<td>-99.99%</td>
</tr>
</tbody>
</table>

• Air absorbs noise at the rate of 6 dB per doubling of distance (point source)

• A typical house attenuates outdoor noise:
  • 15 dB with windows open
  • 25 dB with windows closed
• Lmax - Maximum noise level
• Leq – Equivalent sound level
• SEL - Sound exposure Level
• DNL - Day-night average sound level
• CNEL – Community noise equivalent level
• L_n – Sound level exceeded for a percent of the time
• TA – Time above threshold
• NA – Number of events above
LMAX - MAXIMUM SOUND LEVEL

The maximum sound level for a given event

Lmax = 86 dB

A-weighted level (dB)

Time (seconds)
• Leq is the average sound level over any specified period

  – For an aircraft event, time period will depend on the duration of the event

  – For a set time period (e.g., 1-hour, 8-hour, 24-hour)

  – For a time period that has special meaning (e.g., average noise for when school is in session during a day, only nighttime hours, etc.)
The average sound level for a given period of time is 73 dB.

$L_{max} = 86 \text{ dB}$

$Leq = 73 \text{ dB}$

Duration = 40 seconds

Background noise level (ambient)
SEL - SOUND EXPOSURE LEVEL

• SEL is a measure of the physical energy of the noise event which takes into account both intensity and duration

• SEL takes the energy of an event and compresses it into 1 second

• SEL = 10 LOG ((10^{Leq/10})*T)  
  • Where:  
    T = the time in seconds representing the Leq value (24 hr = 86, 400 sec)  
    For a 24 hour period: SEL = Leq + 49.4

• SEL allows different events to be compared

• SEL enables the addition of multiple events and the calculation of the average of multiple events
The average sound level for a given period of time is called the background noise level (ambient). The duration of this level is 40 seconds.

- SEL (Sound Exposure Level) = 97 dB
- Lmax (Maximum Level) = 86 dB
- Leq (Equivalent Level) = 73 dB

SEL - SOUND EXPOSURE LEVEL
COMPARISON OF DIFFERENT SOUNDS

Aircraft Flyover

Lmax=105 dB
SEL=100 dB
Leq=105 dB
Event Duration=3 sec.

Roadway Noise

Lmax=88 dB
SEL=100 dB
Leq=71 dB
Event Duration=70 sec.

Impulse Noise

Lmax=76 dB
SEL=100 dB
Leq=71 dB
Event Duration=900 sec.
DNL - DAY-NIGHT AVERAGE SOUND LEVEL

• 24-hour time-averaged sound level with a 10 dB nighttime (10:00 pm-7:00 am) weighting

• DNL = Total Daytime Sound Energy + 10 times Total Nighttime Sound Energy divided by Time (in seconds)

• DNL is the metric of choice in the airport world. Its use is required to define noise contours of equal exposure for Part 150 and NEPA studies (other metrics can be used)
• All Federal agencies have adopted DNL as the metric for airport noise analysis

• 65 dB DNL is the threshold that the FAA has established for ‘significant’ impacts (some other agencies have confirmed this threshold while others have suggested lower thresholds)

• ‘Significant’ impacts can translate into sound-insulation for a homeowner

• No matter where the threshold is set, there will always be people living just outside the area
Intrusive Penalty Factor during nighttime hours is due to lower ambient nighttime noise levels and typical sleeping hours.
• State of California uses a metric in place of DNL. CNEL adds an evening period, 7pm – 10pm, with a 4.77 dB weighting

• CNEL = Total Daytime Sound Energy + 4.77 times Total Evening Sound Energy + 10 times Total Nighttime Sound Energy divided by Time (in seconds)
  • CNEL = 10 LOG ((N_{DAY} +4.77* N_{EVE} +10* N_{NIGHT})/86400)

• Generally results in larger noise contours due to the evening penalty
\( L_N \) - PERCENT EXCEEDED

- Sound level exceeded for a percent of the time. Most commonly 10, 50 and 90.

<table>
<thead>
<tr>
<th>Examples</th>
<th>( L_{10} )</th>
<th>( L_{50} )</th>
<th>( L_{90} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>82</td>
<td>76</td>
<td>71</td>
</tr>
<tr>
<td>Site 2</td>
<td>72</td>
<td>68</td>
<td>66</td>
</tr>
<tr>
<td>Site 3</td>
<td>80</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Site 4</td>
<td>65</td>
<td>55</td>
<td>45</td>
</tr>
</tbody>
</table>
• TA represents the time (generally minutes or seconds) that noise is above a given level

• TA is sometimes considered for evaluating speech interference in schools

<table>
<thead>
<tr>
<th>Time-Above (secs)</th>
<th>Baseline</th>
<th>Proposed Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;65 dB</td>
<td>800</td>
<td>1,100</td>
</tr>
<tr>
<td>&gt;70 dB</td>
<td>400</td>
<td>460</td>
</tr>
<tr>
<td>&gt;80 dB</td>
<td>100</td>
<td>115</td>
</tr>
<tr>
<td>&gt;90 dB</td>
<td>20</td>
<td>22</td>
</tr>
</tbody>
</table>
• NA represents the number of events above a specified noise level for a period of time

• NA combines both noise level and number of overflights to develop an expression of the experience

• NA can be a useful tool for explaining what a person is currently experiencing or what they may experience in the future
• The required tool for calculation of aircraft noise contours in studies seeking to make noise mitigation eligible for Airport Improvement Program (AIP) or Passenger Facility Charge (PFC) funding.

• AEDT is a software system that dynamically models aircraft performance in space and time to produce fuel burn, emissions and noise.

• Noise outputs includes noise contours connecting points of equal noise exposure (typically 65, 70, 75 DNL), Tabular information, Noise levels at specific locations (grid point analysis).
• **Airport information** – runways, temperature, airport altitude
• **Where aircraft fly** – flight tracks (definitions and usage)
• **What aircraft are flown** – fleet mix data
• **How often they fly** – operations levels
• **What engines are used** – engine type, hush kit information, etc.
• **What runway** – runway utilization
• **When they fly** – time-of-day characteristics day/night (night=10dB DNL penalty)
• **How they are flown** – climb/descent profiles
• **Where they fly to** – performance data
SUPPLEMENTAL AEDT INFORMATION

- GIS database files
- Terrain files
- Census population files
- Census cartographic files
- Radar track files
The modeled 65 DNL noise contour at O'Hare has shrunk in size consistently since 1979 (right) despite an increase in total aircraft operations because of the replacement of Stage 1 and 2 aircraft with Stage 3 and 4 aircraft mandated by ANCA.
FEDERAL STATUTES GOVERNING AIRCRAFT AND AIRPORT NOISE

• The Federal Aviation Act of 1958
• The Control and Abatement of Aircraft Noise and Sonic Boom Act of 1968
• The Airport and Airway Improvement Act of 1970
• The Noise Control Act of 1972
• Aviation Safety and Noise Abatement Act of 1979
• **Airport Noise and Capacity Act of 1990**
• 14 C.F.R. Part 36: Aircraft Type and Air Worthiness Certification Standards
• 14 C.F.R. Part 91: General Operating and Flight Rules
• 14 C.F.R. Part 150: Airport Noise Compatibility Planning
• 14 C.F.R. Part 161: Notice and Approval of Airport Noise and Access Restrictions
• FAA Order 5050.4B, Airport Environmental Handbook
• **FAA Order 1050.1F, Environmental Impacts: Policies and Procedures**
AIRPORT NOISE AND CAPACITY ACT (ANCA)

• Passed by Congress on November 5, 1990 to establish a "national policy on aviation noise

• Goal was to balance community interests with aviation interests

• Balancing was accomplished in two Federal Air Regulations
  • FAR Part 91
    • Required phase-out of Stage 2 aircraft by December 31, 1999
      (only applies to aircraft > 75,000 pounds)
  • FAR Part 161
    • Restricts airport ability to regulate airport access based on noise
      (Restrictions apply to all aircraft)
**THRESHOLDS OF SIGNIFICANCE**

- The threshold of significance for aircraft noise is incorporated into FAA Order 1050.1F, Appendix A, Paragraph 14.3, which reads as follows:

  *If the above comparisons show a DNL 1.5 dB or greater increase over a noise sensitive area exposed to DNL 65 dB or greater as a result of the proposed project or any of its reasonable alternatives (except no action), a level of significant noise impact has been reached.*

- This level of significance was subsequently re-examined and confirmed by the Federal Interagency Committee on Noise (FICON) in 1992.

  *Confirmed 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe*

  *Recommended the examination of noise-sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more due to the proposed action.*

- As noted in FAA Order 1050.1F, the consideration of mitigation for noise impacts between DNL 60 and 65 “…is not to be interpreted as a commitment to fund or otherwise implement mitigation measures in any particular area.”
• Three Thresholds of Significance to Consider
  1. 65 DNL or greater
  2. 1.5 dB increase inside the 65 DNL
  3. 3.0 dB increase outside the 65 DNL

1 FAA Order 1050.1F, Environmental Impacts: Policies and Procedures
2 With project alternative compared to the no action alternative for the same timeframe
WHO CONTROLS AIRCRAFT NOISE?

• Congress
  • Set Ceiling on Aircraft Noise

• FAA
  • Set Aircraft Noise Certification Levels
  • Review and Approve Noise Compatibility Planning
  • Manage Air Traffic and the National Airspace System

• Airport Proprietor
  • Monitor
  • Abate
  • Mitigate

• State and local government
  • Plan Land Use Compatibility

• Aircraft Operators
  • Fly Quieter Aircraft
  • Follow Noise Abatement Procedures
CONCLUDING THOUGHTS

• There exists a dichotomy between what people experience and what is required in the preparation of environmental and Part 150 studies

• DNL is the best metric available for describing and anticipating long term exposure from aircraft noise

• 65 DNL can be (and should be) debated as the threshold for ‘significant’ impacts

• Metrics that combine single-event impacts with the number of events (like NA) can help build trust in the process and the analysis
Questions?