Aviation Noise Impact: A Historical Perspective

Kenneth J. Plotkin
Wyle Laboratories
December 10, 2009
FAA’s Aviation Noise Impacts Research Roadmap

Objectives

- Improve understanding of noise impacts
  - Annoyance and Sleep in this workshop
- Noise assessments that relate exposure to impacts
- Results that can be implemented via rules and policy
- Findings/tools to help agencies and airports deal with noise
  - Manage public expectation
  - Practical mitigation strategies
- Societal cost inputs to Cost-Benefit models (APMT)

Not the first time for these objectives
“Those who don't know history are destined to repeat it.”
- Edmund Burke, 1729-1797

“Those who do not learn from history are doomed to repeat it” - George Santayana, 1863-1952, whose knowledge of history apparently did not include Burke.

• How did aviation noise metrics evolve?
• What was lost during the evolution?
• What was gained along the way?
• What was never considered?
• Need a number that quantifies two items:
  - How loud is it?
  - How often does it happen?

• Classic Loudness weightings:
  - A: low levels
  - B: medium levels
  - C: high levels

• Aircraft noise studies in the 1950s:
  - C (high levels) did not correlate with loudness
  - A worked better
  - PNL (Kryter) worked even better
Composite Noise Rating
(Loudness based on PNL)
(Numbers based on $10 \log_{10} N$)

## U.S. History of Aviation Noise Metrics

### 1950s
- **CNR**

### 1960s
- **NEF**

---

**Noise Exposure Forecast**
*(based on EPNL – PNL with duration and tone)*

<table>
<thead>
<tr>
<th>Distance from Site to the Center of the Area Covered by the Principal Runways</th>
<th>Acceptability Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside the NEF-30 (CNR-100) contour, at a distance greater than or equal to the distance between the NEF-30 and NEF-40 (CNR-100, CNR-115) contours</td>
<td>Clearly Acceptable</td>
</tr>
<tr>
<td>Outside the NEF-30 (CNR-100) contour, at a distance less than the distance between the NEF-30 and NEF-40 (CNR-100, CNR-115) contours</td>
<td>Normally Acceptable</td>
</tr>
<tr>
<td>Between the NEF-30 and NEF-40 (CNR-100, CNR-115) contours</td>
<td>Normally Unacceptable</td>
</tr>
<tr>
<td>Within the NEF-40 (CNR-115) contour</td>
<td>Clearly Unacceptable</td>
</tr>
</tbody>
</table>

---

**Threshold at NEF = 30**

**Equivalent to DNL = 65**

Source: HUD Noise Assessment Guidelines, BBN Report 2176, August 1971
*(For aircraft noise exposure)*
Community Noise Equivalent Level
(Developed by Wyle for California, 1968)
(based on dBA, with duration)

5012. Airport Noise Criteria. Limitations on airport noise in residential communities are hereby established.
(a) The criterion community noise equivalent level (CNEL) is 65 dB for proposed new airports and for vacated military airports being converted to civilian use.
(b) Giving due consideration to economic and technological feasibility, the criterion community noise equivalent level (CNEL) for existing civilian airports (except as follows) is 70 dB until December 31, 1985, and 65 dB thereafter.
(c) The criterion CNEL for airports which have 4-engine turbojet or turbofan air carrier aircraft operations and at least 25,000 annual air carrier operations (takeoffs plus landings) is as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>CNEL in decibels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective date of regulations to 12-31-75</td>
<td>80</td>
</tr>
<tr>
<td>1-1-76 to 12-31-80</td>
<td>75</td>
</tr>
<tr>
<td>1-1-81 to 12-31-85</td>
<td>70</td>
</tr>
<tr>
<td>1-1-86 and thereafter</td>
<td>65</td>
</tr>
</tbody>
</table>

Day-Night Average Noise Level (based on dBA)

<table>
<thead>
<tr>
<th>EFFECT</th>
<th>LEVEL</th>
<th>AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing Loss</td>
<td>$L_{eq(24)} &lt; 70 \text{ dB}$</td>
<td>All areas</td>
</tr>
<tr>
<td>Outdoor activity interference and annoyance</td>
<td>$L_{dn} &lt; 55 \text{ dB}$</td>
<td>Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.</td>
</tr>
<tr>
<td></td>
<td>$L_{eq(24)} &lt; 55 \text{ dB}$</td>
<td>Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.</td>
</tr>
<tr>
<td>Indoor activity interference and annoyance</td>
<td>$L_{dn} &lt; 45 \text{ dB}$</td>
<td>Indoor residential areas</td>
</tr>
<tr>
<td></td>
<td>$L_{eq(24)} &lt; 45 \text{ dB}$</td>
<td>Other indoor areas with human activities such as schools, etc.</td>
</tr>
</tbody>
</table>

Continuing Equivalencies of Noise Metrics

<table>
<thead>
<tr>
<th>Period</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950s</td>
<td>CNR</td>
</tr>
<tr>
<td>1960s</td>
<td>NEF</td>
</tr>
<tr>
<td>1970</td>
<td>CNEL</td>
</tr>
<tr>
<td>1974</td>
<td>DNL</td>
</tr>
<tr>
<td>1980</td>
<td>FICUN</td>
</tr>
</tbody>
</table>

**TABLE 1. NOISE ZONE CLASSIFICATION**

<table>
<thead>
<tr>
<th>Noise Exposure Class</th>
<th>DNL: Day-Night Average Sound Level</th>
<th>Leq(hour): Equivalent Sound Level</th>
<th>NEF: Noise Exposure Forecast</th>
<th>HUD Noise Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Not Exceeding 55</td>
<td>Not Exceeding 55</td>
<td>Not Exceeding 20</td>
<td>&quot;Acceptable&quot;</td>
</tr>
<tr>
<td>B</td>
<td>Above 55 But Not Exceeding 65</td>
<td>Above 55 But Not Exceeding 65</td>
<td>Above 25 But Not Exceeding 30</td>
<td>&quot;Acceptable&quot;</td>
</tr>
<tr>
<td>C-I</td>
<td>Above 65 But Not Exceeding 70</td>
<td>Above 65 But Not Exceeding 70</td>
<td>Above 30 But Not Exceeding 35</td>
<td>&quot;Normally Unacceptable&quot;</td>
</tr>
<tr>
<td>C-2</td>
<td>Above 75 But Not Exceeding 75</td>
<td>Above 70 But Not Exceeding 75</td>
<td>Above 35 But Not Exceeding 40</td>
<td>&quot;Unacceptable&quot;</td>
</tr>
<tr>
<td>D-1</td>
<td>Above 75 But Not Exceeding 80</td>
<td>Above 80 But Not Exceeding 80</td>
<td>Not Exceeding 45</td>
<td>&quot;Unacceptable&quot;</td>
</tr>
<tr>
<td>D-2</td>
<td>Above 80 But Not Exceeding 85</td>
<td>Above 85 But Not Exceeding 85</td>
<td>Above 45 But Not Exceeding 50</td>
<td>&quot;Unacceptable&quot;</td>
</tr>
<tr>
<td>D-3</td>
<td>Above 85</td>
<td>Above 85</td>
<td>Above 50</td>
<td>&quot;Unacceptable&quot;</td>
</tr>
</tbody>
</table>

Source: FICUN Guidelines for Noise in Land Use Planning and Control, June 1980.

Consolidation of metrics beneficial to general land use planning
Equal Energy Principle

- Adoption of DNL meant acceptance of the *Equal Energy principle*

- Single events are quantified by their energy:
  \[ SEL_i = 10 \log_{10} \int 10^{L_i/10} dt \]

- Multiple events are energy sum of single events
  \[ L_{eq} = 10 \log_{10} \frac{1}{T} \sum_i 10^{SEL_i/10} \]

- These are the easiest metrics to model
  - SEL is simple sound power integral
  - Separate sources add independently: no statistical interaction. Familiar “decibel addition”

- Would be nice if these correlated with individual and community reaction
Equal Energy Principle

- Established for single events: 3 dB/ doubling duration
- Presumed to apply to total exposure time

But is it really universal?

24 Hour Exposure

- Figure that multiple events can be energy summed to SEL or average over a longer period

- Early analyses considered
  - Daytime noise: mostly speech interference
  - Nighttime noise: mostly sleep disturbance

- Single daily number would be useful
  - Calculate average daytime and nighttime noise levels
  - Add 10 dB penalty to nighttime level
  - Combine via energy addition
    - NEF combined day/night equally, so whichever is bigger will dominate. Effectively $16.67 N_{night}$ multiplier
    - CNEL, DNL applied adjustment hour-by-hour, so the night multiplier is $10 N_{night}$
  - Morphed into the concept of a cumulative 24 hour dose
# Classic Cumulative Metrics

## Metrics in use around 1970

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>SCALE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A.</td>
<td>CNR</td>
<td>[\text{PNL} + 10 \log_{10} N - 12]</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>NEF</td>
<td>[\text{EPN} + 10 \log_{10} N - 88]</td>
</tr>
<tr>
<td>France</td>
<td>(N)</td>
<td>[\text{PNL} + 10 \log_{10} N - 30]</td>
</tr>
<tr>
<td>Great Britain</td>
<td>NNI</td>
<td>[\text{PNL} + 15 \log_{10} N - 80]</td>
</tr>
<tr>
<td>Germany</td>
<td>(\overline{Q})</td>
<td>[\text{PNL} + 13.3 \log_{10} N - 52.3]</td>
</tr>
<tr>
<td>South Africa</td>
<td>(\overline{NT})</td>
<td>[\text{PNL} - 13 + 10 \log_{10} N - 39.4]</td>
</tr>
<tr>
<td>Netherlands</td>
<td>B</td>
<td>[\frac{20}{15} (\text{PNL} - 13) + 20 \log_{10} N - C]</td>
</tr>
<tr>
<td>I.C.A.O.</td>
<td>WECNL</td>
<td>[\text{EPN} + 10 \log_{10} N - 39.4]</td>
</tr>
</tbody>
</table>

\[10 \log_{10} N \text{ is equal energy across events}\]
Early Community Noise Reaction Analysis

Community Reaction

- Vigorous action
- Several threats of legal action or strong appeals to local officials to stop noise
- Widespread complaints or single threat of legal action
- Sporadic complaints
- No reaction although noise is generally noticeable

Data normalized to:
- Residential urban residual noise
- Some prior exposure
- Windows partially open
- No pure tone or impulses

Early Use of Adjustments to Reduce Spread

Adjustments other than evening and night penalties have fallen out of use

Popular conception that DNL 65 was a policy decision based on this.

Note that the plot is effect vs DNL. This has become “the” way to view noise impact.
Schultz Curve Has Been Reworked

Will one more point of the same kind (i.e., %HA vs DNL) make a difference?
... but still has some questions

Does changing where we draw the curve change:

- How communities react?
- How people are affected?

Does a single curve make sense?

- There are modal differences (air, rail, road)
- Should there be a distribution at each level?

Since 1990, 95% of surveys have been overseas.
Food for Thought

- Equal energy principle dominates, partly for reasons not necessarily related to science
- Schultz curve has been reworked many times
- Relationship between DNL and annoyance has high degree of uncertainty.
- Most of the social surveys are over 20 years old (>60%).
- All recent social surveys have been done overseas (Europe and Japan).

- Basics that were simplified need to be revisited. Other metrics (like current “supplementary”) may better reflect impact.
- Would another similar data point really make a difference?
- Would different metric(s) reduce uncertainty? Is %HA versus DNL the only way?
- What are the influences of changes in public attitudes and aircraft characteristics?
- Do Americans have a different attitude about their environment?