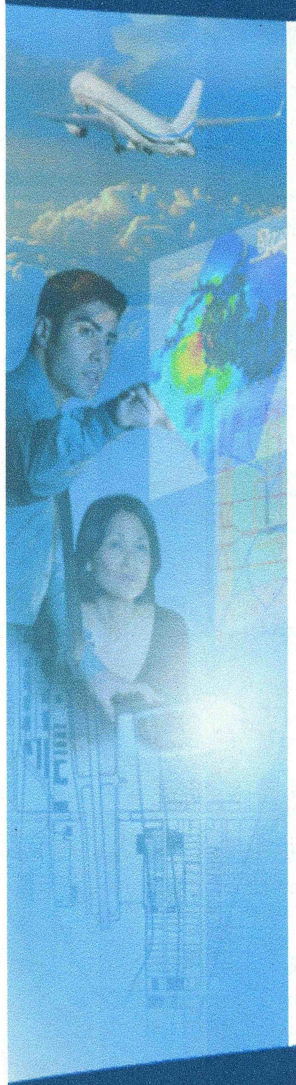
Integrity Reliability Innovation Service



Aviation Noise Impact: A Historical Perspective

Kenneth J. Plotkin

Wyle Laboratories

December 10, 2009

wyle

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

wyle

Learn from the Past

"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*.

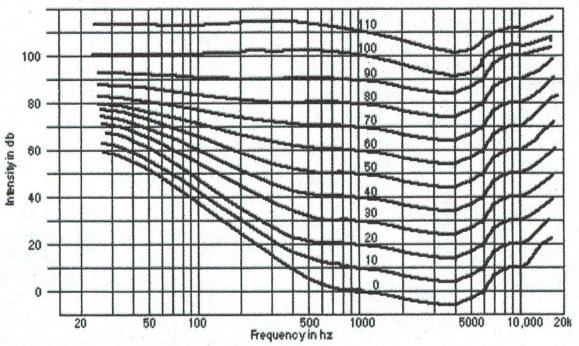
- How did aviation noise metrics evolve?
- What was lost during the evolution?
- What was gained along the way?
- What was never considered?

wyle

Noise Metrics

- 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

Fletcher-Munson curves



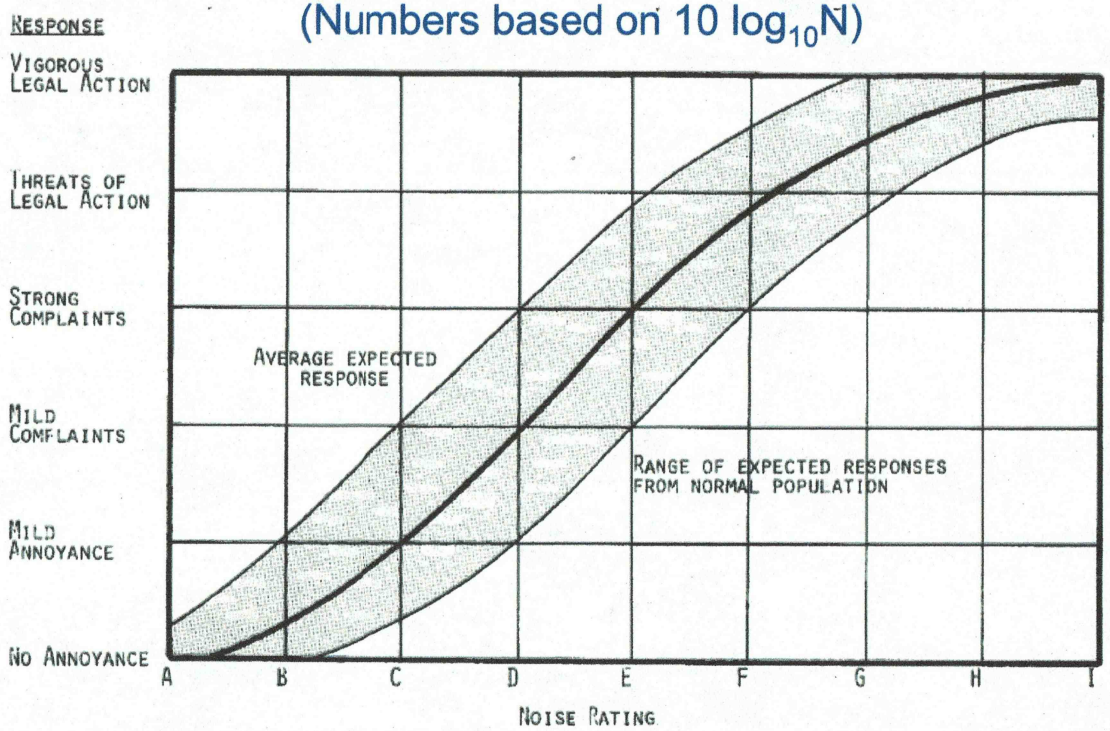
- Aircraft noise studies in the 1950s:
  - C (high levels) did not correlate with loudness
  - A worked better
  - PNL (Kryter) worked even better

wyle

U.S. History of Aviation Noise Metrics

1950s CNR

Composite Noise Rating
(Loudness based on PNL)
(Numbers based on 10 $\log_{10}$N)



Source: Kryter, K. D. Human Reactions to Sound from Aircraft. J. Acoust. Soc. Am. 31: 1415-1429. 1959.

wyle

U.S. History of Aviation Noise Metrics

1950s CNR

1960s NEF

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

Threshold at NEF = 30

Equivalent to DNL = 65

TABLE I.

SITE EXPOSURE TO AIRCRAFT NOISE

Distance from Site to the Center of the Area Covered by the Principal Runways	Acceptability Category
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	Clearly Acceptable
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	Normally Acceptable
Between the NEF-30 and NEF-40 (CNR-100, CNR-115) contours	Normally Unacceptable
Within the NEF-40 (CNR-115) contour	Clearly Unacceptable

Source: HUD Noise Assessment Guidelines, BBN Report 2176, August 1971
(For aircraft noise exposure)

wyle

U.S. History of Aviation Noise Metrics

1950s CNR

1960s NEF

1970 CNEL

dBA reasonably approximates PNL

65 dB criterion formally specified

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:

Date	*CNEL in decibels*
Effective date of regulations to 12-31-75	80
1-1-76 to 12-31-80	75
1-1-81 to 12-31-85	70
1-1-86 and thereafter	65

Source: Title 4, California Administrative Code §5000. Department of Aeronautics, Subchapter 6. Noise Standards. (Register 70, No. 48 -- 11-28-70).

wyle

EPA: Noise Metrics Become Generic

1950s CNR

1960s NEF

1970 CNEL

1974 DNL

Consolidated diverse noise metrics and criteria. Emphasized effects.

Day-Night Average Noise Level
(based on dBA)

Table 1
SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY
(see Table 4 for detailed description)

EFFECT	LEVEL	AREA
Hearing Loss	$L_{eq(24)} \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	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.
	$L_{eq(24)} \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq(24)} \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

Source: EPA Levels Document EPA 550/9-74-004, March 1974

wyle

Continuing Equivalencies of Noise Metrics

1950s CNR

1960s NEF

1970 CNEL

1974 DNL

1980 FICUN

TABLE 1. NOISE ZONE CLASSIFICATION

Noise Zone	Noise Exposure Class	Noise Descriptor			HUD Noise Standards
		DNL[1] Day-Night Average Sound Level	$L_{eq(hour)}$[3] Equivalent Sound Level	NEF[4] Noise Exposure Forecast	
A	Minimal Exposure	Not Exceeding 55	Not Exceeding 55	Not Exceeding 20	"Acceptable"
B	Moderate Exposure	Above 55[2] But Not Exceeding 65	Above 55 But Not Exceeding 65	Above 25 But Not Exceeding 30	
C-1	Significant Exposure	Above 65 Not Exceeding 70	Above 65 Not Exceeding 70	Above 30 But Not Exceeding 35	"Normally Unacceptable"[5]
C-2		Above 70 But Not Exceeding 75	Above 70 But Not Exceeding 75	Above 35 But Not Exceeding 40	
D-1	Severe Exposure	Above 75 But Not Exceeding 80	Above 40 But Not Exceeding 80	Not Exceeding 45	"Unacceptable"
D-2		Above 80 But Not Exceeding 85	Above 80 But Not Exceeding 85	Above 45 But Not Exceeding 50	
D-3		Above 85	Above 85	Above 50	

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

Consolidation of metrics beneficial to general land use planning

wyle

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

$$L_{eq} = 10\log_{10}\frac{1}{T}\sum_i 10^{SEL_i/10}$$

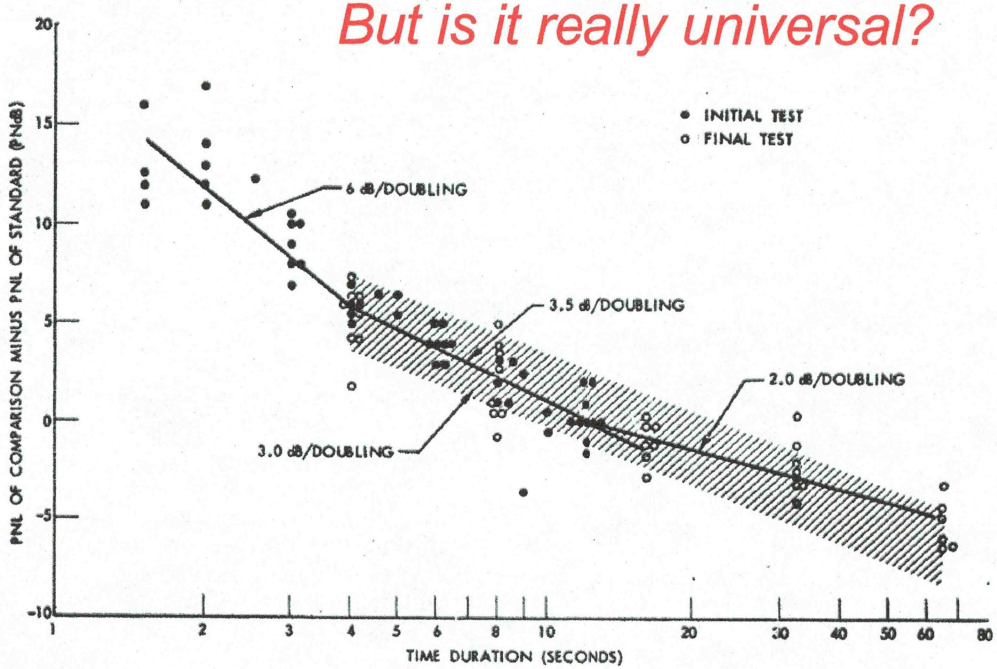
- These are the easiest metrics to model
  - SEL is simple sound power integral
  - Separate sources add independently: no statistical interaction. Familiar "decibel addition"
- Would be nice if these correlated with individual and community reaction

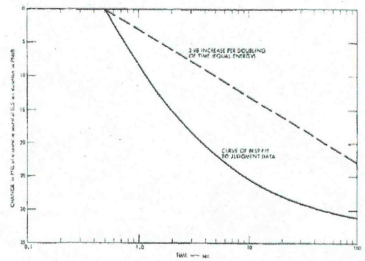
wyle

Equal Energy Principle

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

But is it really universal?





Pearsons, FAA ADS-78, 1966.

Source: Kryter, *The Effects of Noise on Man*, 1971.

wyle

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

wyle

Classic Cumulative Metrics

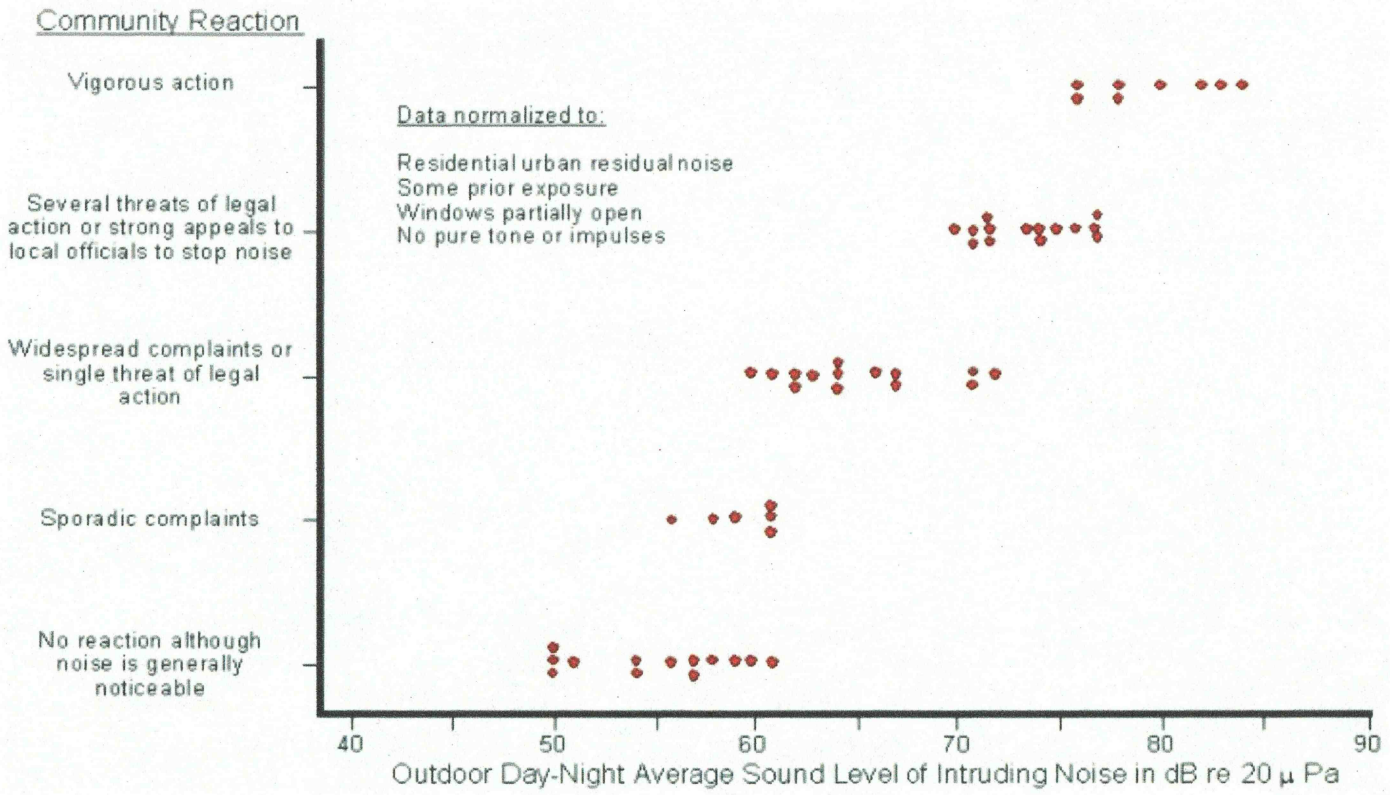
Metrics in use around 1970

COUNTRY	SCALE	DEFINITION
U.S.A.	CNR	$= PNL + 10 \log_{10} N - 12$
U.S.A.	NEF	$= EPN + 10 \log_{10} N - 88$
France	$\mathcal{N}$	$= PNL + 10 \log_{10} N - 30$
Great Britain	NNI	$= PNL + 15 \log_{10} N - 80$
Germany	$\overline{Q}$	$= PNL + 13.3 \log_{10} N - 52.3$
South Africa	$\overline{NI}$	$= PNL - 13 + 10 \log_{10} N - 39.4$
Netherlands	B	$= \frac{20}{15} (PNL - 13) + 20 \log_{10} N - C$
I.C.A.O.	WECNL	$= EPN + 10 \log_{10} N - 39.4$

$10 \log_{10} N$ is equal energy across events

wyle

Early Community Noise Reaction Analysis



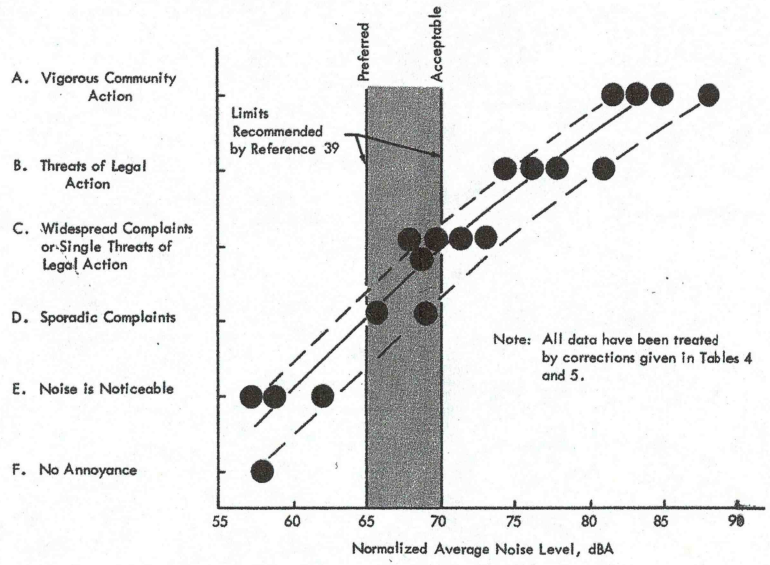
Source: EPA Levels Document EPA 550/9-74-004, March 1974

wyle

Early Use of Adjustments to Reduce Spread

CORRECTION FACTORS FOR NORMALIZING COMMUNITY NOISE CASES TO A SINGLE MAGNITUDE SCALE

Type of Correction	Description	Amount of Correction to the Measured Noise Levels, dBA
Seasonal Correction	Summer (Year-around operations)	0
	Winter only	-5
Time of Day	Daytime	0
	Evening	+5
	Nighttime	+10
Correction for Background Noise	Very quiet suburban or rural community (remote from large cities and from industrial activity and trucking)	+10
	Normal suburban community (not located near industrial activity)	+5
	Residential urban community (not immediately adjacent to heavily traveled roads and industrial areas)	0
	Noisy urban community (near relatively busy roads or industrial areas)	-5
Correction for Previous Exposure and Community Attitudes	Community has had some previous exposure to aircraft noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to aircraft noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to aircraft noise, and airport relations with the community are good.	-5
	This correction can be applied for an operation of limited duration and under emergency circumstances; it cannot be applied for an indefinite period.	-10

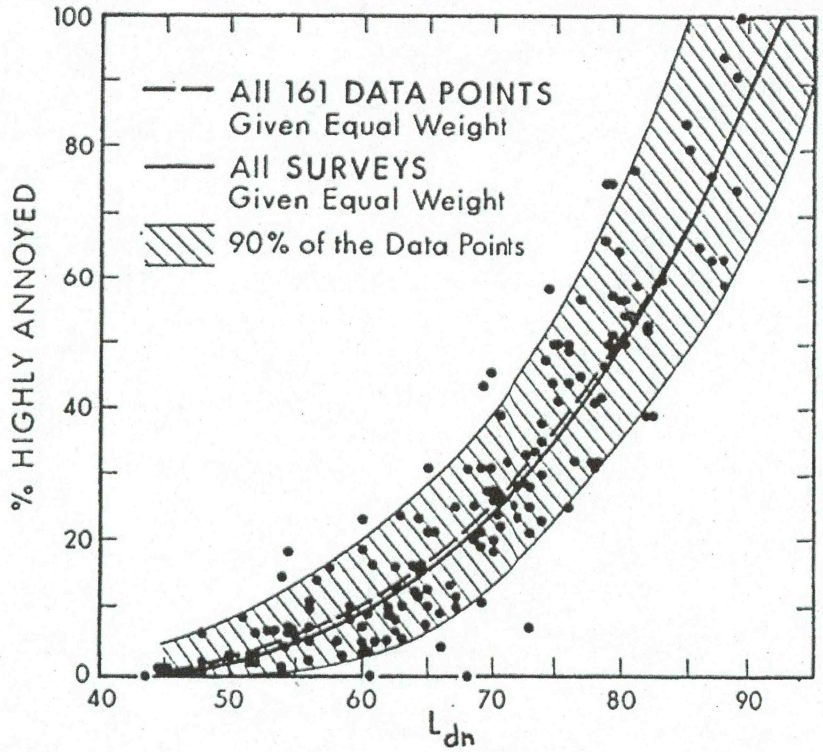


Adjustments other than evening and night penalties have fallen out of use

Source: Supporting Information for the Adopted Noise Regulations for California Airports, Wyle Report 70-03. 1971.

wyle

Schultz Curve Original Version - 1978



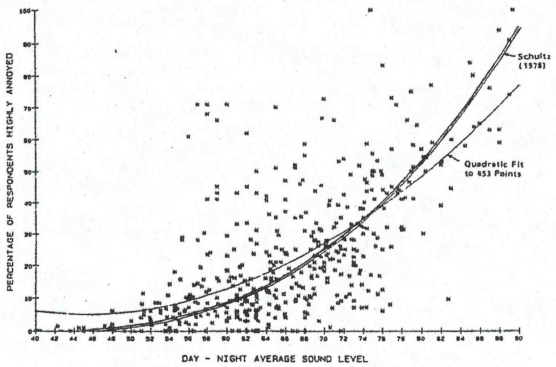
Note that the plot is effect vs DNL. This has become "the" way to view noise impact.

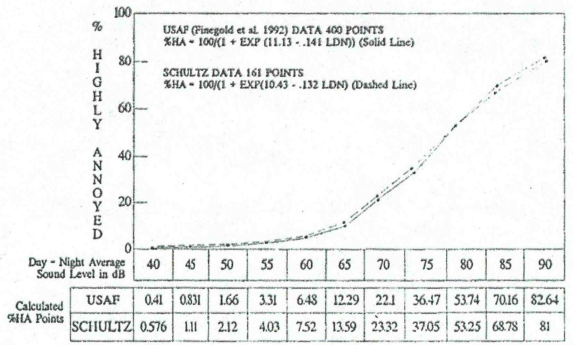
Popular conception that DNL 65 was a policy decision based on this.

wyle

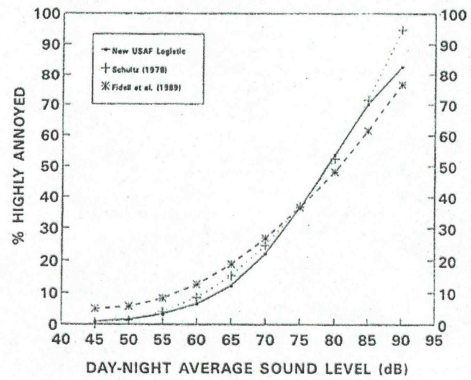
Schultz Curve Has Been Reworked

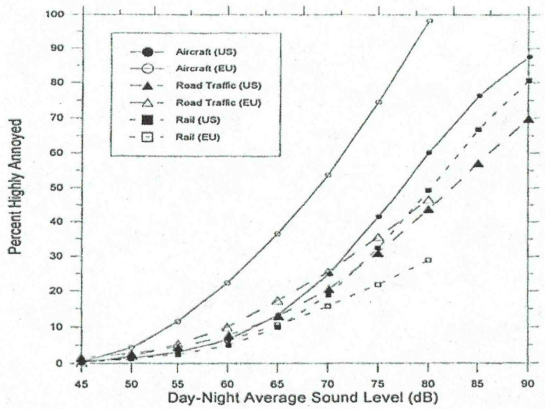
Will one more point of the same kind (i.e., %HA vs DNL) make a difference?





Day - Night Average Sound Level in dB	40	45	50	55	60	65	70	75	80	85	90
Calculated %HA Points: USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
Calculated %HA Points: SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81





U.S.Data: Finegold, L.S., "Community Annoyance and Sleep Disturbance: Updated Criteria for Assessing the Impacts of General Transportation Noise on People", Noise Control Eng. J. 42 (1), 1994
EU Data: Miedema, H.M.E., "Response Functions for Environmental Noise in Residential Areas", TNO-Report 92.021, Leiden, The Netherlands, 1992

wyle

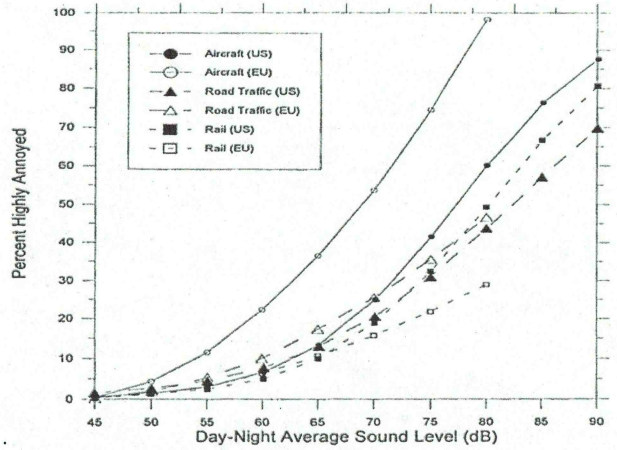
… but still has some questions

Does changing where we draw the curve change:

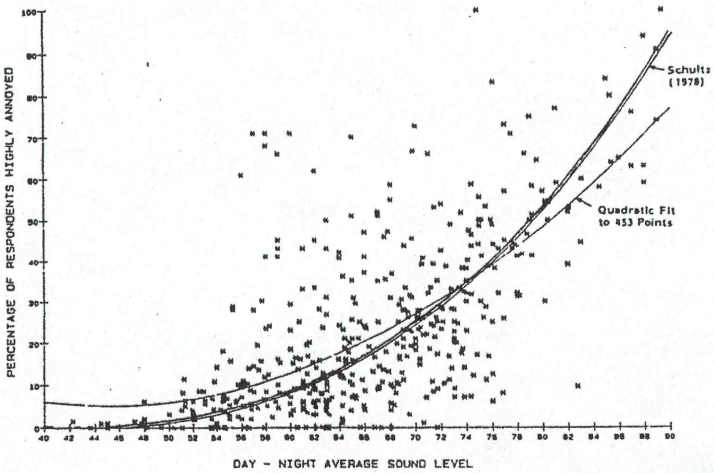
- **How communities react?**
- **How people are affected?**

Does a single curve make sense?

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

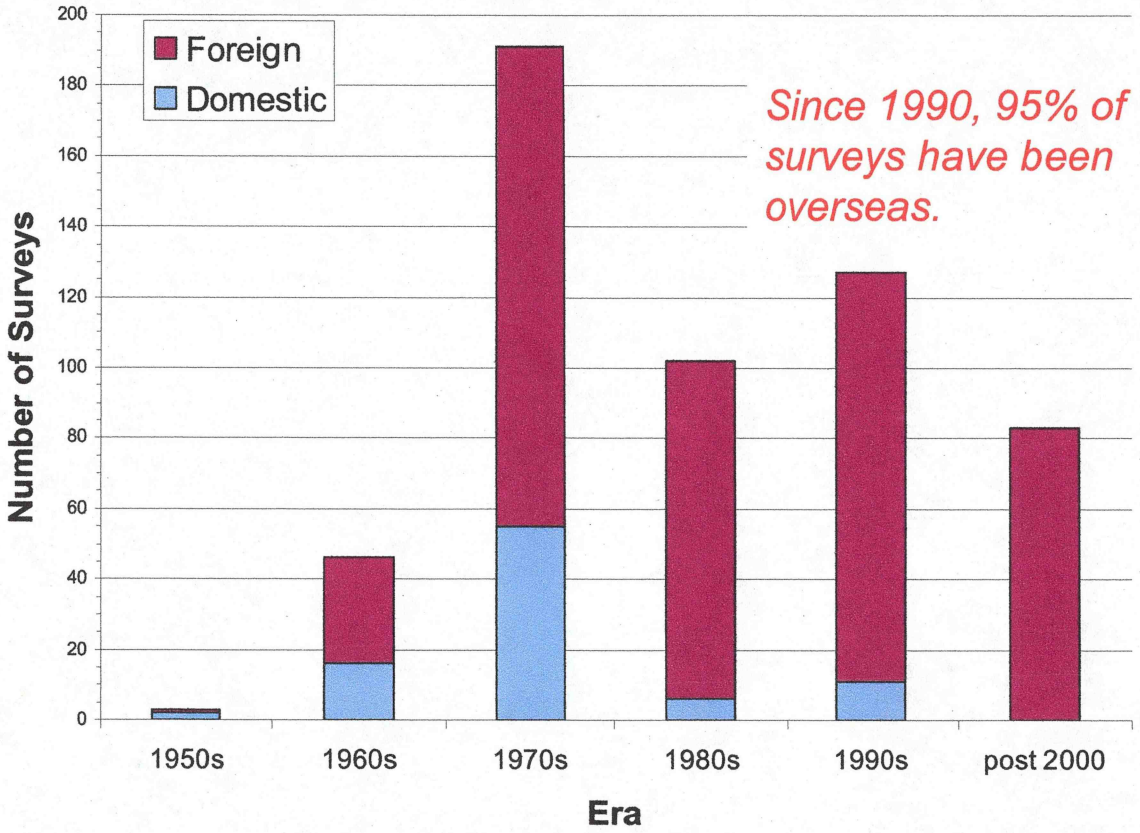


U.S.Data: Finegold, L.S., "Community Annoyance and Sleep Disturbance: Updated Criteria for Assessing the Impacts of General Transportation Noise on People", Noise Control Eng. J. 42 (1), 1994
EU Data: Miedema, H.M.E., "Response Functions for Environmental Noise in Residential Areas", TNO-Report 92.021, Leiden, The Netherlands, 1992



wyle

Social Surveys on Community and/or Transportation Noise



Data from: Bassarab, R., Sharp, B., and Robinette, B., "An Updated Catalog of Social Surveys of Residents' Reaction to Environmental Noise," Wyle Report 09-18, November 2009. (Also DOT/FAA/AEE/2009-01 and DOT-VNTSC-FAA-10-02.)

wyle

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?*

wyle