A Review of US Aircraft Noise Regulatory Policy

Introduction

Vigorous community opposition to aircraft noise exposure is more the rule than the exception at airports worldwide, particularly when efforts are made to increase airport capacity or change operational patterns. Since the introduction of commercial jet service in the late 1950s, these disputes have often been highly contentious, to the point of intense political debate and costly litigation. Beranek (2008) provides a notable account of one of the earliest US aircraft noise controversies. The ongoing, national-level debate in the United Kingdom over the addition of a runway to a London-area airport is a current example. Noise-related airport-community controversies are ongoing at airports in many US cities, including Chicago, Ft. Lauderdale, Minneapolis, all of the major New York airports (not to mention East Hampton), Phoenix, and Santa Monica.

The contentiousness of airport-community controversies arises in large part from disparities in the distribution of costs and benefits of air transportation. Most of the noise-related costs of air transportation but relatively few of its benefits accrue to overflown populations near airports. Other interests, including those of the traveling public, airlines, and airports, enjoy more of the benefits of air transportation but bear few of its costs.

National aircraft noise regulatory practices rarely succeed in accurately predicting or securing public acceptance of aircraft noise exposure in airport-vicinity communities. Weaknesses of aircraft noise regulation are traceable in large part to obselete and overly simplified policies that ignore nonacoustic influences on community response. This review of US aircraft noise regulation describes its origins, rationale, complexities, and limitations.

The review extends to modern technical understandings that may help improve the efficacy of aircraft noise regulation. It is now possible to systematically derive regulatory thresholds for noise exposure values from two parameters: (1) the perception of the population of a hypothetically average community to be protected from exposure to highly annoying aircraft noise and (2) the percentage of all communities to which such protection is intended to apply (Fidell et al., 2014).

Some Legislative, Political, and Judicial Background

Commercial aviation in the United States has been favored as a public good by the US Congress in much the same way that it once viewed railroads and highways. Government subsidies to aviation have included lucrative airmail contracts in the 1920s; creation of nationwide, federally funded aerial navigation and air traffic control systems; limitation, until 1978, of commercial airline competition by maintenance of barriers to entry; much military and other aviation research; and export financing. When the Civil Aeronautics Board regulated airfares, airlines even had a federal guarantee of return on investment! Airports have long enjoyed the use of federal and municipal capital for infrastructure construction; access to federal trust funds for mitigating noise impacts; and tax-advantaged municipal bond markets for project financing, even after starting to convert themselves in the 1980s from municipal utilities into shopping malls with runways nearby.

Because regulatory agencies in the United States are creatures of legislatures, aircraft noise has consequently been regulated with a light touch. The US Congress has, with few exceptions, provided policy direction that has yielded a playing field steeply tilted in favor of aviation interests. Public Law 85-726, the much-amended 1958 legislation that originally established the Federal Aviation Administration (FAA) as an independent agency, assigned a “dua1 mandate” to the agency: not only to regulate the national air transportation network for purposes of safety and efficiency but also to actively promote civilian aviation. Although Congress relieved the FAA of this inherent conflict of interest in the 1996 Department of Transportation Reauthorization Act, the agency has yet to revise its noise regulatory policies to reflect the revised Congressional direction.

US airports also received generally favorable treatment, at least until a 1962 Supreme Court ruling in Griggs vs. Allegheny County assigned liability for noise damages exclusively to airport proprietors rather than to airlines (owners of the noise sources) or to the federal government (responsible for directing the movements of the noise sources while in flight). The ruling freed airlines and the FAA from liabilities for adverse environmental effects of exposure to commercial aircraft noise while leaving airports deeply ensnared in aircraft noise disputes. Today’s aircraft noise regulatory environment would be very different had the Supreme Court ruled otherwise.

Aircraft Noise Metrics

Airport-community disputes of all kinds generally center on aircraft noise exposure. The baroque set of aircraft noise metrics that has been proposed over several decades for quantifying aircraft noise is a tribute to the collective imagination of generations of acousticians, environmental noise researchers, academics, consultants, politicians, and technocrats. Schultz (1972), Bennett and Pearsons (1981), and Mestre et al. (2011), among others, have catalogued the alphabet soup of noise rating schemes intended to predict community response to aircraft noise. The focus on aircraft noise measurement in airport-community controversies is sometimes so close that the underlying purpose for quantifying aircraft noise is overlooked. Aircraft noise is not measured simply for measurement’s sake but as a means to an end. For regulatory purposes, aircraft noise is measured to quantitatively predict its effects (“impacts” in the environmental analysis vernacular) on noise-exposed populations. If aircraft noise did not disturb sleep, interfere with speech, and annoy people, however, few would find it worth the bother and considerable expense of measurement in the first place. It follows that any noise metric that does not support a reliable prediction of community response to noise does not play a useful role in aircraft noise regulation.

Aircraft noise experienced in airport communities varies simultaneously and greatly in the amplitude, frequency, and time domains. As illustrated in Figure 1, within about half a minute, an individual overflight heard in an airport neighborhood characteristically emerges from the neighborhood ambient-noise environment into noticeability as an aircraft approaches an observer on the ground; increases in sound level more or less steadily often by 30 dB or more, as the aircraft approaches; changes continuously in character and frequency content due to the directivity of its narrow- and wideband engine and aerodynamic noise sources; and finally, decreases in sound level as the overflight recedes from the observer until it merges back into ambient-noise levels. In neighborhoods near the ends of runways, overflights may recur at about two-minute intervals, more or less continuouly, throughout many hours of the day and night.

Day-Night Average Sound Level

What aspect of such aircraft noise events constitutes the “best” measure of them: their frequency-weighted maximum level, individual duration, total number, energy average, temporal distribution, dynamic range, variance, tonal content, signal-to-noise ratio, rise and decay times, Doppler shift, or some other yet more subtle characteristic? The Airport Safety and Noise Act (ASNA) of 1979 (Public Law 96-193) required the Secretary of Transportation to identify a single, universally applicable aircraft noise measure—
Aircraft Noise Regulation

Noise Effect of Greatest Concern for Regulatory Purposes

The rationale for FAA noise regulatory policy is described by the Federal Interagency Committee on Noise (FICON,1992). FICON states that “…the percent of the exposed population expected to be highly annoyed (“HA”) is the most useful metric for characterizing or assessing noise impact on people,” and that “…the updated ‘schultz curve’ remains the best available source of empirical dosage-effect information to predict community response to transportation noise.” The “Schultz curve” is an early dosage-response relationship (Schultz, 1978) linking transportation noise exposure to the prevalence of a consequential degree of transportation noise-induced annoyance in communities. The original analysis by Schultz has been revisited several times in subsequent decades and is now obsolete.

DNL is used in environmental impact disclosure documents as a required metric of noise exposure. However, the public does not fully appreciate the difference between DNL itself and the interpretive criteria that the FAA applies to DNL. The result is that the metric is widely misunderstood and misinterpreted. For regulatory purposes, it is equally sensitive to all of them. Thus, if the number of aircraft operations changes by a factor of two (that is, by 3 dB), or if the duration of aircraft overflights changes by a factor of two, or if the acoustic energy of individual aircraft overflights changes by 3 dB, so does DNL. In practice, this means that DNL is highly correlated with all sensible measures of aircraft noise.

The equal energy hypothesis stems from beliefs dating to the 1950s, that the findings of laboratory studies of the acoustic determinants of annoyance can be freely generalized to community settings; and (2) annoyance with residential exposure to aircraft noise can be adequately accounted for in exclusively acoustic terms.

With the advantage of hindsight, these assumptions about the causes of community annoyance with transportation noise exposure appear naive, but to the World War II generation of acousticians who first made them, they seemed quite plausible and worthy of careful investigation. After decades of subsequent research, neither of the above assumptions has proven to be tenable. In closely controlled laboratory measurements (of the sort described by Zwicker and Fastl [1999], for example), reliable differences can be observed in the ability of frequency-weighted measures of aircraft noise levels to predict individual annoyance judgments. In uncontrolled (real world) settings, however, community annoyance is not controlled by acoustic factors alone. Difficulties in measuring and predicting aircraft noise levels lead to further uncertainty in estimating noise-exposure levels.

Rationale for Basing Aircraft Noise Regulation on Cumulative Noise Exposure

The tacit belief underlying use of DNL to predict community response to aircraft noise is known as the “equal energy” hypothesis. The hypothesis holds that annoyance with aircraft noise exposure is equally influenced by the number, duration, and acoustic energy of aircraft noise exposure. In other words, the equal energy hypothesis asserts that it is not simply the sound level of an aircraft overflight, the duration of individual overflights, or the number of overflights that controls its annoyance but the multiplicative product of all three.

Because DNL values reflect the simple product of all of the primary factors (sound level, duration, and number) that can reasonably affect the annoyance of aircraft noise exposure, it is equally sensitive to all of them. Thus, if the number of aircraft operations changes by a factor of two (that is, by 3 dB), or if the duration of aircraft overflights changes by a factor of two, or if the acoustic energy of individual aircraft overflights changes by 3 dB, so does DNL. In practice, this means that DNL is highly correlated with all sensible measures of aircraft noise.

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Why Regulate Aircraft Noise?

All regulation seeks to balance conflicting societal interests. In the case of aircraft noise, the conflicting interests include satisfying nationwide demand for air transportation services, maintaining the habitability of local neighborhoods near airports and the integrity of local government tax bases, and protecting both public investment in airport infrastructure and private residential property values.

The public conception of the purpose of aircraft noise regulatory policy in the vicinity of airports is to protect some percentage of residential populations from exposure to highly annoying aircraft noise. This is not the FAA’s primary purpose, however. The agency sees protection of public investment in airports as the primary purpose for noise regulation. For example, the FAA’s “land use compatibility” guidelines are intended to restrict land uses around airports that do not threaten continued operation and unfettered expansion of airports.

The FAA lacks authority to mandate off-airport uses for land that airports do not own. It is therefore careful to characterize its preferences for airport-vicinity land uses as advisory (cf. the well-known footnote to Table 1 of Appendix A of FAR Part 150) rather than mandatory, in large part to avoid reasuring any of the noise liability of which the Supreme Court relieved the agency in 1962. In effect, the FAA interprets its charter as protecting airports from communities.

The foundational questions that aircraft noise regulatory policy must answer are “How much noise is too much?” and “How can you tell?” The FAA’s answers to these questions are that noise impacts due to aircraft noise exposure at $L_{dn} < 65$ dB do not rise to a level of “significance,” and that FICON’s 1992 report somehow or other supports the FAA’s policy interpretation that noise impacts associated with aircraft noise exposure at $L_{dn} > 65$ dB are insignificant.

As with other issues in aircraft noise controversies, the customary answers to these questions are, in H. L. Mencken’s (1949) words, appealingly “neat, plausible, and wrong.” Although the FAA and other national regulatory bodies worldwide assert that their regulatory decisions are “fact and science based,” the assertion does not withstand scrutiny. To understand why aircraft noise regulatory policy is not technologically credible, it is helpful to understand the scientific progress that has been made in understanding community response to transportation noise since the 1950s.
on engineering judgment such as that of Galloway and Pi-

in the above equation are assumptions of convenience based

to 9 nighttime hours is taken into account. Both constants

number of operations) when the ratio of 16 daytime hours

The constant 16.7 represents a 10-dB nighttime penalty

was NEF = CNR − 72 dB.

The approximate relationship between NEF and CNR values

and (2) to avoid confusion between CNR and NEF values.

The initial systematic efforts to predict community response to

On the basis of little more than engineering judgment in-
formed by field experience, much of it near military airbas-
es, NEF values of 30 dB or less were thought to be suitable for
aircraft noise exposure in areas of single-family detached
dwellings. NEF values between 30 and 40 dB were thought of
as tolerable in neighborhoods of higher density housing,
and NEF values in excess of NEF = 40 dB were thought of as
suitable only for industrial and recreational purposes. When
NEF values were supplanted by DNL values after publication
of EPA’s Levels Document in 1974, a further “correction” of
35 dB was added to NEF values to distinguish them from
DNL values.

All of the above corrections, adjustments, and constants

were based on the personal opinions of acoustical consul-
tants practicing in the 1950s through 1970s, not on large-
scale systematic research. All long precede ASNA’s direction
to the FAA, FAA’s land use compatibility guidelines were
summarized in a 1980 report issued by a “Federal Inter-
agency Committee on Urban Noise (FICUN)” that describes
“land use compatibility” with airports, not reciprocally
together airports and communities. None of the interpre-
tations of compatibility made in the FICUN report were
supported by any form of comprehensive, community-
theory-based, peer-reviewed, or otherwise objective study,
and none have been meaningfully revised. What informally
seemed to some to be an acceptable level of noise pollution
near military airfields six decades ago is not necessarily still
acceptable in modern civil society.

What’s Wrong with
FICON’s 19822 Analyses?

The FAA cites a technical report (FICON, 1992) produced
by a self-appointed Federal Interagency Committee on
Noise as the technical basis for its policy preferences. The
report asserts that the dosage-response relationship shown in
Figure 2 reliably predicts the percentage of a nominally
average community that is highly annoyed by the cumula-
tive noise exposure of a community on a hypothetical an-

dal annual average day. The FICON dosage-response relationship
was devised to update a key linkage between aircraft noise
exposure and community response that had been developed by
Schultz (1978).

Schultz’s 1978 “synthesis” study was the earliest large-scale
examination of a fragmented international literature on the

annoyance attributable to a community’s transportation
noise. Successors to Schultz’s dosage-response function con-
tinue to provide the technical underpinnings of modern stan-
dards such as International Standard 1996-1 (2016).

Ground breaking as it was four decades ago, Schultz’s 1978
dosage-response relationship was already obsolete by 1992.
Both Schultz’s and FICON’s dosage-response relationships were flawed in important ways. Most obviously, they failed to
distinguish among the annoyance of aircraft and other
forms of transportation noise exposure. Decibel for decibel,
communities are more tolerant of road and rail noise than of
aircraft noise (Miedema and Vos, 1998). Including the an-

The concept of “community response” to noise has served since the late 1970s as an informal term for the percentage of a representative sample of noise-exposed residents who describe themselves as conversely annoyed by transportation noise. This percentage has been measured directly in many field studies of community response to aircraft noise exposure since the first modern social survey of this kind was undertaken at London Heathrow Airport (McKendall, 1963).

Figure 2. Dosage-response relationship developed by Federal Inter-
agency Committee on Noise (FICON, 1992) and endorsed by the
Federal Aviation Administration (FAA) for predicting the prevalence
of high annoyance in communities from cumulative exposure to air-
craft noise. %HA, percent of the exposed population expected to be
highly annoyed; Ldn, Day-Night Average Sound Level.

Figure 3. Illustration of the great variability in field measurements of
aircraft noise-induced annoyance prevalence rates in approximately
550 communities.

Figure 4. Summary of worldwide observations of the prevalence
of all transportation noise-induced annoyance. The solid curve in the
figure is a dosage-response relationship relied on in the United States
to predict annoyance prevalence rates in all communities at all trans-
portation noise sources.
The population is highly annoyed by aircraft noise exposure of 
information indicates that, on average, about 28% of the 
noise-induced percentages of high annoyance for a community of av-
nerage tolerance for aircraft noise. For example, the FICON dosage-response relationship 
illustrates the differences between FICON (1992) and the latest analysis of the prevalence of high annoyance 
communities of lesser than average tolerance for noise exposure. It also underestimates annoyance in actual com-
relationship can greatly overestimate annoyance in actual 
annoyance due to aircraft noise exposure is blind to 
dosage-response relationships fashioned by regression tech-
For example, the FICON dosage-response relationship predicts that 12.3% of the residential population is 
and the demographic characteristics of overflown popula-
Figure 5. Comparison of FICON (1992) and International Orga-
nization for Standardization (ISO; 1996-1) predictions of aircraft 
noise-induced percentages of high annoyance for a community of av-
Dosage-response relationships 
and other technically justifiable analyses. FAA 
noise regulatory policy has not attempted to keep up with 
changes in the societal acceptability of pollution over the 
last six decades, with the improved technical understanding of 
noise effects, or even with the post-1996 changes in the 
agency's Congressional charter. 
The FAA's constant numerical definition of significant noise impacts does not recognize empirically measurable differ-
ences in tolerance for noise exposure among communities, and 
thus does not provide a uniform effect on a national ba-
sis. In actual application, the FAA's definition of the signifi-
cance of aircraft noise exposure affords unexpectedly little 
protection of noise-exposed populations in many communi-
ties from consequential degrees of annoyance due to trans-
portation noise.

Systematic means are now available for analyzing popula-
tion percentages in different communities associated with 
particular definitions of noise impacts. The efficacy and effi-
ctivity (univariate regression-based) analyses (Wilson et 
al., 2013). The additional variance is explained by a second 
variable, community tolerance level (CTL), rep-
resented symbolically in mathematical expressions as \( L_a \), 
that accounts for the aggregate effect of all nonacoustic in-
fluences on annoyance judgments. 

CTL analysis follows from the observation that the rate of 
growth of community annoyance with transportation noise 
exposure closely resembles the rate of growth of loudness with sound level. A CTL value is an estimate of DNL value at 
which half of a community describes itself as highly annoyed 
by transportation noise exposure. The range of CTL values 
derived from social survey measurements of reactions to 
aircraft noise in 44 communities extends over three orders 
of magnitude (from roughly 55 dB \( \leq L_a \leq 85 \text{ dB} \)), equivalent 
to a factor of about 1,000:1 in community-specific tolerance for 
aircraft noise exposure. 

For reasons explained by Fidell et al. (2011), annoyance 
prevalence rates in CTL analyses are predicted as

\[
A \quad \text{(highly annoyed)} = e^{A_{\text{SN}}} \quad \text{(1)}
\]

where \( A \) is a scalar nonacoustic decision criterion originally 
described by Fidell et al. (1988), and \( m \) is an estimated noise 
dose calculated as

\[
m = (10^{(\text{DNL}/10)})^3 \quad \text{(2)}
\]

and CTL is calculated from \( A \) as

\[
\text{CTL} = 33.3 (\log_{10} A) + 5.32 \quad \text{(3)}
\]

The value of \( A \), an entirely nonacoustic parameter and hence 
of CTL, expresses the aggregate effect of all of the non-dose-
related factors that influence annoyance prevalence rates in a 
community. The parameter \( A \) translates a dosage-response 
relationship of a fixed shape along the abscissa. 
The distribution of \( A \) values across communities can be de-
termined from databases of community-specific social sur-
vey findings. The empirical distribution of \( A \) values across 
communities is shown in Figure 6 (from Fidell et al., 2014). 

Figure 6 shows that the shape of the distribution of toler-
ance for aircraft noise exposure among communities is log normal. A few communities are highly tolerant of 
aircraft noise exposure, but most are relatively intolerant. Predic-
tions of community response to aircraft noise exposure that 
fail to take the shape of this distribution into account, such 
as those that apply only to a hypothetical community of av-
average tolerance for aircraft noise, are likely to be appreciably 
in error in most communities. Thus, regulatory policy that 
ignores empirically verifiable differences across communi-
ties in tolerance for noise exposure cannot have a uniform 
effect nationwide. 

Summary 
The FAA's definitions of the significance of noise exposure do not protect the supposed percentage of people in most 
US communities from exposure to highly annoying aircraft 
noise (Fidell et al., 2014). Legacy policies concerning the 
'significance' of noise impact and the compatibility of land 
uses (with airports) are based on informal engineering judg-
ments made as early as the 1950s, and on the FAA's (now re-
sinded) charter to promote civil aviation rather than on any 
peer-reviewed or other technically justifiable analyses. FAA 
noise regulatory policy has not attempted to keep up with 
changes in the societal acceptability of pollution over the 
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portation noise.

Systematic means are now available for analyzing popula-
tion percentages in different communities associated with 
particular definitions of noise impacts. The efficacy and ef-

Figure 6. Histogram of scalar quantity (A) in 44 communities ex-
posed to aircraft noise.
ciency of regulatory policies expressed in acoustic units can now be gauged simply by specifying two parameters: (1) the percentage of the population of a nominally average community to be protected from high annoyance and (2) the percentage of people in all communities to be similarly protected (Fidell, 2014).

Acknowledgments

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Biosketch

Sanford Fidell began his transportation noise research and consulting work in the Los Angeles office of Bolt, Beranek, and Newman (BBN) in 1968. In 33 years at BBN, he directed theoretical, laboratory, and field research in many areas of psychoacoustics and environmental acoustics. He has continued his research, consulting, and expert witness work on community response to noise and acoustic signal detection after forming Fidell Associates in 2001.

References