UPDATING AND SUPPLEMENTING THE DAY-NIGHT AVERAGE SOUND LEVEL (DNL)

WR 11-04

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Prepared for:

The Volpe National Transportation Systems Center

Updating and Supplementing the Day-Night Average Sound Level (DNL)

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Abbreviations, Acronyms, and Symbols

CNEL	Community Noise Equivalent Level
CNR	Composite Noise Rating
CNR-A	Composite Noise Rating - Aircraft
CNR_C	Early (1952) community noise metric
DNL	Day-Night Average Sound Level
EDNL/EDENL	EDNL/EDENL
EPA	Environmental Protection Agency
EPNL	Effective Perceived Noise Level
FAA	Federal Aviation Administration
FICON	Federal Interagency Committee On Noise
HNL	Hourly Noise Level
L_{dn}	Day-Night Average Sound Level
L_{dnmr}	Onset-Rate Adjusted Monthly Day-Night Average Sound Level
$L_{eq(16)}$	$L_{eq(16)}$
$L_{eq\ (period)}$	Equivalent Sound Level
L_r	Rating Sound Level
NA	Number-of-events Above
NC	Noise Criteria
NEF	Noise Exposure Forecast
NNI	Noise and Number Index
NPL	Noise Pollution Level
NR	Noise Rating Curves
PK15(met)	Peak Noise Exceeded by 15 Percent of Firing Events
PNL	Perceived Noise Level
PNLT	Tone-corrected Perceived Noise Level
SEL	Sound Exposure Level
TA	Time Above
TAUD	Time Audible
TNI	Traffic Noise Index
WECPNL	Weighted Equivalent Continuous Perceived Noise Level

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SECTION 1

Introduction

The Day-Night Average Sound Level, DNL, is the cornerstone of aviation noise impact analysis in the United States*. There are two current concerns about this metric. The first is whether, having been in place for several decades, it is still the best fit for today's communities and aircraft types. The second is that the public does not easily understand it, so that despite its scientific support it does not facilitate communication with communities.

1.1 DNL, Community Response and Annoyance

DNL's roots can be traced back to the Composite Noise Rating (CNR)[1-3] of the 1950s. CNR began in a form where aircraft noise spectra were compared to reference spectra at various levels, in a manner similar to Noise Criteria (NC)[4] curves used for assessment of interior ventilation system noise. Noise was quantified by a letter rank. The process included adjustments for time of day (effectively a 5 dB penalty for night), ambient conditions, season, and various physical characteristics of the noise. CNR was supported by surveying community response to measured noise,[2] and it was noted even then that factors other than noise had a role in response.

The basic concepts in CNR evolved into forms with more detail and an understanding of underlying effects. Spectral content was addressed by appropriate loudness metrics, rather than comparison of spectra. The duration of events was accounted for with data from listening studies, numbers of events were accounted for from listening and field studies, and ratings were presented on decibel scales. By the 1960s this evolution led to use of Noise Exposure Forecast (NEF)[5] which represented the frequency content of noise by perceived noise level (PNL) which was based on laboratory listening tests specialized to aircraft noise. A variation of PNL, PNLT included tone correction, and EPNL accounted for duration of events. Multiple events were combined on an energy summation basis. NEF included a 10 dB adjustment for nighttime events, an early change from CNR's initial 5 dB.

In the 1970s the use of NEF for airport noise contours was replaced by DNL (initially denoted L_{dn}, a notation still in use, often interchangeably with DNL). This was a consolidation of metrics between government agencies, seeking one which applied to all community noise sources, and accepting compromise in details for particular sources.

The background for DNL is well presented in the EPA "Levels" document,[6] and in the background document for the California's Community Noise Equivalent Level (CNEL) metric.[7] DNL and CNEL are very similar, with CNEL containing a 5 dB evening penalty in addition to the 10 dB nighttime penalty. The evening period is reflected in the similar L_{den} metric used in Europe. Other than night (or evening) adjustments, neither metric contains the situational adjustments that were present in CNR, although the CNEL background document presents them and shows that if they were applied they would reduce scatter in annoyance response data.

Practical considerations such as the mathematical form of prediction models also entered into the evolution from CNR. Energy summation metrics are much easier to handle than most other forms, so there is great value in using that kind of metric as long as there is no evidence that it is less adequate than others.

References 6 and 7 present the background for DNL in two ways. One is by assessing specific impacts of noise. The primary impacts considered are speech interference, sleep disturbance, hearing damage, and non-auditory health effects. The other is by analysis of the results of surveys of community response to noise.

* Variation Community Noise Equivalent Level (CNEL) is used in California.

The second method, analysis of community surveys, attained significant prominence in 1978 when Schultz published his synthesis of social surveys,[8] showing that data from eleven surveys, when characterized as percent of people highly annoyed as a function of DNL, were remarkably consistent with each other. This yielded a dose-response curve that was easy to apply to quantify noise impact.

Figure 1 is Schultz's original curve. Since its publication, many more social surveys have become available, as shown in Figure 2, which is based on data contained in Wyle's recent updated catalog of social surveys.[9] That catalog lists 628 surveys, far more than the 18 that Schultz considered and the 11 that he used in his analysis. Researchers have invested considerable effort in revising the curve to reflect the additional data. Figure 3 shows the current version of the Schultz curve, as endorsed by FICON.[10] It does not differ markedly from the original, and does not reduce the scatter.

While the Schultz curve is a valuable tool, it tends to give the impression that community noise impact is well represented by a single dose-response curve based on DNL. The curve is often treated as a black box, to be derived from social surveys and improved by curve fits of additional data. With so many data points in the current form, and the rather small differences with improved versions, it is questionable how much might be gained from continuing that kind of approach.

FIGURE 1 ***Original Schultz Curve, based on 11 Surveys and 161 Data Points***

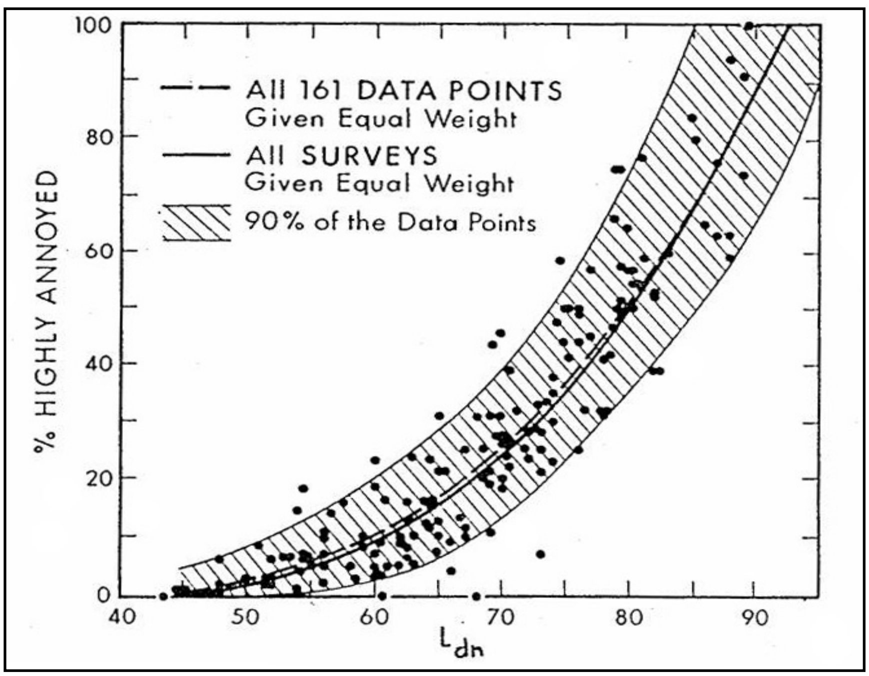


FIGURE 2 *Numbers of Social Surveys by Year and Location*

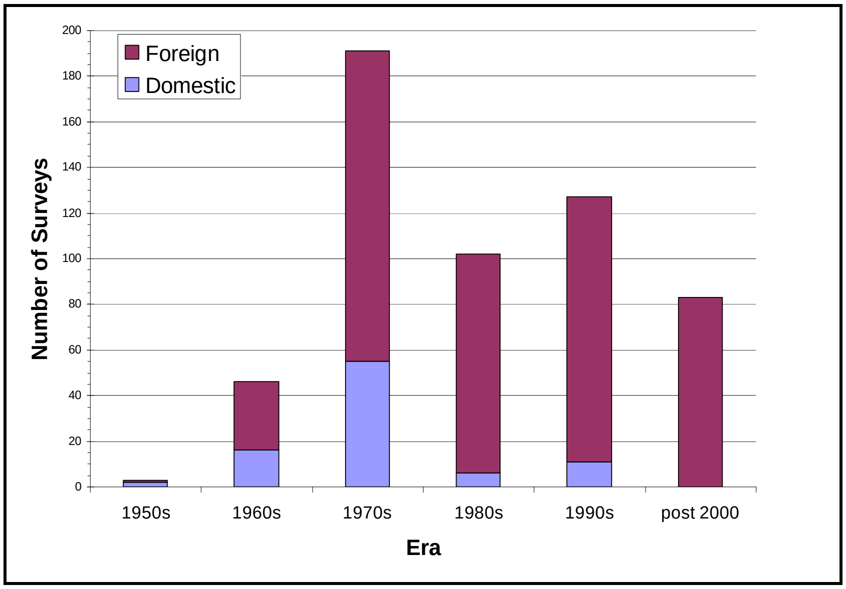
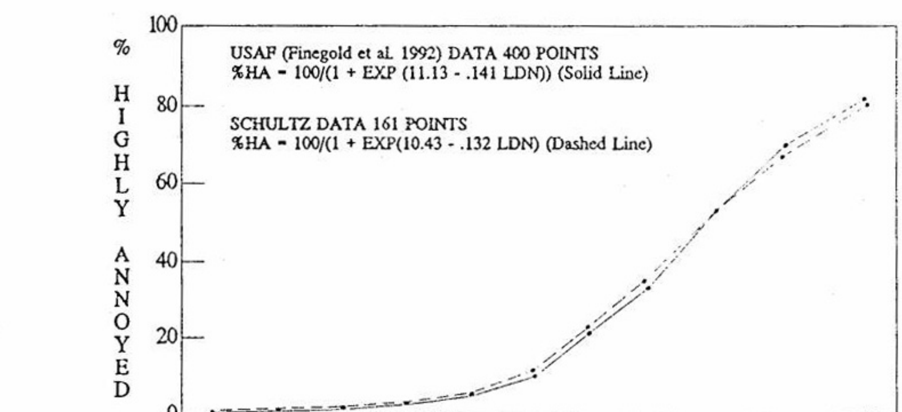


FIGURE 3 *Current version of Schultz Curve, Compared with Original*



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
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

1.2 Annoyance as a Multivariate Function

Community noise impact is best viewed as a multivariate function of the form of Equation (1)

$$R = f(M_1, M_2, M_3, \ldots M_x) \quad (1)$$

where R is the community response to aircraft noise exposure and M_i represent major contributing direct acoustic and indirect non-acoustic factors. R can represent a variety of adverse effects. The following are generally considered to be the direct effects of noise:

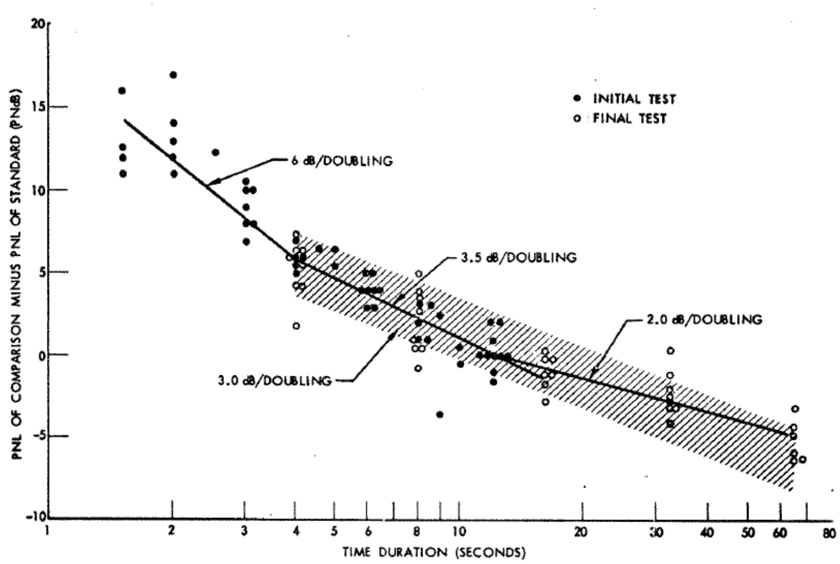
- Speech interference;
- Sleep disturbance;
- Task interference;
- Impairment of classroom learning;
- Non-auditory health effects; and
- Aversive effects on emotion and tranquility.

Currently, for airports in the United States, R is "annoyance," which represents the aggregate of these effects, and function f is the Schultz curve. The only M is DNL. The objective of the current study is to identify how the response function R can be improved via different, or additional, metric(s).

Although presented as a single curve, the Schultz curve is implicitly multivariate because DNL itself is comprised of several components. The components are:

- A-weighting represents how levels are perceived. It was a feasible replacement for the more elaborate tone-corrected perceived noise level (PNLT) because, in the 1970s, the kind of strong single tones present in earlier jet aircraft were vanishing.
- The use of energy summation over an event, i.e., SEL, is supported by laboratory studies of the tradeoff between level and duration, as illustrated in Figure 4.[11]

FIGURE 4 ***Trade between Sound Level and Duration [Equal energy (SEL, 3 dB per doubling) fits data for event times between a few seconds and a minute typical of aircraft noise]***



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- Energy summation over multiple events is supported by social surveys, experiments involving the public (such as Reference 12), or compressed scale laboratory studies (such as Reference 13).
- The 10 dB night penalty is based on either the concept that noise intrusion is relative to ambient levels, which are lower at night, or that noise disturbs sleep.

A simple "black box" approach does not shed light on whether particular effects are addressed in a metric. In general, it is necessary to understand the functional role of each parameter, and seek data in which the parameters are truly independent. Fields,[14] for example, has pointed out that around most airports daytime and nighttime noise exposures are highly correlated, so that an understanding of nighttime effects (whether ambient level or sleep disturbance) usually cannot be separated by simple regressions.

Evolution over time is significant. By the 1960s PNL and EPNL represented sophisticated handling of aircraft spectral effects, and the change to simple A-weighting was undertaken with an understanding of the change in sources that permitted this step. Aircraft today do not sound the same as they did in the 1970s. Additionally, the pattern of aircraft noise is different. Levels are substantially lower than they were when DNL was adopted, but the numbers of operations has increased dramatically. Improvements of noise impact modeling must review details that may have been considered in the past, and not just seek new metrics.

In addition to quantitative scientific issues, management of annoyance from aircraft noise involves communication with the public. Because DNL is not readily understood by the public, and does not relate directly to some effects, it is common to include other metrics to help describe an expected noise environment. FICON[10] noted the use of supplemental metrics, and encouraged development as needed to suit agencies needs. It has become common to present supplemental metrics to the public, with varying degrees of emphasis depending on circumstances. To formalize this procedure, the Department of Defense contracted with Wyle to prepare guidelines for the use of supplemental metrics.[15] These are effective in communication with the public. Some, like those relating to speech interference or sleep disturbance, have quantitative relation to impact. Others, like number above (NA) or presentations of flight tracks, do not have quantitative meaning but help the public understand the environment. Both types are of interest for the current study, either as potential enhancements or replacements for DNL or as supplemental descriptive and communication tools.

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SECTION 2

Study Approach

This study is directed at identifying improved or supplemental noise metrics for community annoyance. Quantifying particular impact effects, such as sleep disturbance or speech interference, as well as general annoyance, is of interest. Available data to compute these metrics were to be identified. Necessary data which do not yet exist were to be identified.

Wyle's team consisted of the following members:

- Dr. Kenneth Plotkin (Wyle);
- Dr. Ben Sharp (Wyle);
- Tom Connor (Wyle);
- Royce Bassarab (Wyle);
- Dr. Ian Flindell (University of Southampton); and
- Dirk Schreckenberg (ZEUS GmbH).

A work plan consisting of the following steps was prepared as follows:

1. List all relevant acoustic metrics and non-acoustic factors. A comprehensive list of metrics was compiled from sources that included Wyle Report WR 09-18, "An Updated Catalog of 628 Social Surveys of Residents' Reaction to Environmental Noise (1943-2008)," NASA CR-2376 "Handbook of Noise Ratings," NASA CR-3406 "Handbook of Aircraft Noise Metrics," and relevant standards activities.

   WR 09-18 is a comprehensive catalog of surveys, and was a primary source of information on existing data. More recent data, and studies outside of the United States, such as the current COSMA project in Europe, were assessed with the assistance of our European consultants.

   The full list of metrics was thinned to remove those that were clearly duplicates or obsolete. The list was further downselected, as described under steps 2 and 3 below, based on current understanding of social surveys and community interactions that use the various metrics.

   Relevant non-acoustic factors were compiled from sources that include Wyle Report 70-03, "Supporting Information for the Adopted Noise Regulations for California Airports," and LVNL, Air Traffic Control the Netherlands, Report D/R&D 07/260 version 1.0, "Noise Annoyance Mitigation at Airports by Non-Acoustic Measures".

2. A spreadsheet was prepared with background, purpose, and applicability of each metric:

   - Identify direct impacts quantified by single event metrics;
   - Score noise metrics on applicability, ease of computation, etc.; and
   - Identify non-acoustic factors that act as modifiers.

   Most metrics are used worldwide, but there are some used in Europe and not in the US. Our European consultants provided expert knowledge on those metrics, as well as European experience with widely used metrics.

3. Single event metrics relevant for direct impact on communities were identified, e.g., SIL for speech interference or PNLT to account for tonal components.

4. The relation between single event metrics and their combination into cumulative metrics was examined.

   - Identify the form of *R* for those metrics; and
   - Identify the use of modifiers.

   In particular, the methods used to develop those forms were examined.

5. Existing data for computation of selected metrics was identified. This included data that relates to direct effects, and data that relates to the modifiers.

6. Data shortfalls, and recommendations made on how necessary data can be acquired.

It should be noted that noise impact metrics draw from a range of types of studies, not just social surveys. Loudness metrics (e.g., A-weighting and PNL) are derived from controlled laboratory studies, and tend to correlate well with each other, with variances of a few dB when applied to particular classes of sounds. Those differences are not readily resolved from social surveys, where many more variables are present and resolutions of perhaps 5 or 10 dB are expected. Community noise metrics evolved from a natural sequence of studies that ranged from laboratory listening experiments through social surveys. For example, the experiment described in Reference 13 was part of a series of studies. It was preceded by a laboratory study[16] that quantified the loudness effect (onset rate) being examined and was followed by an in-home study[17] that confirmed the effect in a setting closer to a social survey. The planning for that series, whose purpose was to develop an adjustment for a particular effect (rapid onset rates of fast moving military aircraft) defined a sequence that consisted of 1) anecdotal observation of issues among residents, 2) laboratory listening tests of the loudness of that effect, 3) controlled non-laboratory listening tests in a more realistic setting, 4) surveying of subjects in their own homes with some staging of events, and 5) social survey. The staged noise events in the fourth step permitted statistical separation of variables in a way that would not have been possible relying only on as-flown flight operations during the study period.

Emphasis in the current project is on identifying data sources from social surveys. Effects that require other types of studies are noted.

SECTION 3

Inventory of Noise Metrics, Effects, and Non-Acoustic Factors

A list of all relevant noise factors, metrics and non-acoustic factors was compiled. It was intended to list non-acoustic factors that could be associated with various noise metrics. It was, however, found that very few non-acoustic factors were associated with particular noise metrics. CNR did include a number of such adjustments, but by the time CNEL had evolved those factors were no longer applied to metrics or threshold criteria. The night (or evening) penalty might be construed as a non-acoustic factor, but that would be a stretch because its origins are acoustic. That left WECPNL, with its seasonal adjustment based on numbers of days where temperatures fall in each of three ranges, as the only metric with a direct non-acoustic factor. Leaving aside that one instance, direct acoustic factors are thus limited to the physical characteristics of noise, including level, spectral content, duration, and time of day. These are represented by metrics which are presented in Section 3.1. Non-acoustic factors are presented and discussed in Section 3.2.

3.1 Noise Metrics

Metrics were divided into three categories:

- Levels, as measured at some instant or for a steady sound;
- Single event metrics, which quantify the impact of one event, accounting for its time varying level and duration; and
- Cumulative metrics, accounting for noise over an extended period and encompassing a number of events.

Fifteen level metrics, four single event metrics and nineteen cumulative metrics were identified. These were organized into a spreadsheet that described their origin, format, status, and applicability to aircraft noise. Table 1 lists the metrics, in an abbreviated form of the spreadsheet. Parts a, b and c list each type.

Each metric was then rated according to four practical considerations:

- Suitability for aircraft noise;
- Meaningfulness;
- Understandability; and
- Ease of calculation and modeling.

The metrics were scored by the team members listed earlier. Table 2 lists the characteristics considered and the scoring criteria.

Table 3 shows the scoring results. Some candidate metrics - such as C-weighting - were summarily dismissed. Of the remaining ones, each of the six team members scored each metric in each of the four categories. For each metric, the average score is shown for each of the four criteria. The sum of those four scores is then shown as "Total." In principle, there would be 24 ratings per metric. If a team member was not familiar with a particular metric, however, no score was given. The column "#Votes" shows how many scores each metric received. A low number of votes indicate unfamiliarity in the scientific community, which would exacerbate the issue of finding metrics understandable to the public.

The final column in Table 3 is a synopsis and summary judgment of each metric. The final downselection considered this summary as well as the numeric scores.

Table 4 lists the metrics, in each category, that remained after the downselection. Under each category, the first line represents mainstream metrics that are represented by DNL and equivalent equal energy metrics. Subsequent lines represent other metrics that are relevant (in whole or in part) as alternatives or for supplemental use. L_{Amax10}, the maximum A-weighted level exceeded by the loudest 10 percent of the aircraft noise events was added after the final downselection. This is a candidate supplemental metric that places emphasis on sound levels, as opposed to NA, TA and respite that place emphasis on time and numbers.

Table 1a. Candidate Level Metrics

Metric	Abbreviation or Symbol	Origin/History	Impact Measured	Formulation
Sound Pressure Level (A-weighted)	L_A	Approximation to Fletcher-Munson curves for low levels.	Level as perceived by humans	Frequency weighting.
Sound Pressure Level (B-weighted)	L_B	Approximation to Fletcher-Munson curves for medium levels.	Medium levels	Frequency weighting.
Sound Pressure Level (C-weighted)	L_C	Approximation to Fletcher-Munson curves for high levels	High amplitude level perceived by humans	Frequency weighting.
Perceived Level	PL	Quantifies loudness. Mark VII evolved from Stevens Mark VI.	Loudness	Computed from octave or third octave spectra.
Perceived Noise Level	PNL	Quantifies noisiness, similar to PL for loudness. Developed for aircraft noise. Foundation of CNR.	Noisiness	Computed from octave or third octave spectra. The unit is PNdB.
Tone Corrected Perceived Noise Level	PNLT	PNL with tone correction. Developed for aircraft noise. Foundation of NEF.	Noisiness	Computed from octave or third octave spectra. The unit is PNdB.
Noise Criteria Curve	NC	Interior noise.	Ambient level, particularly for speech communication	Sets of octave band spectra. NC is the lowest curve not exceeded in any band.
Preferred Noise Criterion	PNC	Interior noise.	Updated NC	
Articulation Index	AI		Speech communication	Signal to noise ratio in 20 bands from 200 Hz to 6100 Hz. "Signal" is a normal male voice.
Speech Interference Level	SIL	Simplification of AI.	Speech communication, particularly among aircraft passengers	Arithmetic average of octave bands in the speech frequency range.
Low Frequency Noise Level	LFNL	Low frequency metric, developed in response to low frequency noise issues at selected airports.	Community annoyance from low frequency noise	Composite maximum of levels in third octave bands from 25 Hz through 80 Hz.
E-Level (E-weighted Sound Pressure Level)	L_E or EL	Approximation of the inverse of the 20 Sone PL curve.	Loudness, as an approximation to PL	Frequency weighting.
D-Level (D-weighted Sound Pressure Level)	L_D or DL	Approximation to the inverse of the 40 Noy curve	Noisiness, as an approximation to PNL	Frequency weighting.
Sound quality metrics	Various			Various

Table 1b. Candidate Single Event Metrics

Metric	Abbreviation or Symbol	Origin/History
Effective Perceived Noise Level	EPNL	Event-integrated PNLT.
Single Event Noise Exposure Level	SENEL	Original (now obsolete) nomenclature for SEL.
Sound Exposure Level	SEL, L_{AE}	Sound energy integrated over an event. Essentially L_{eq} before dividing by the time period.
C-weighted Sound Exposure Level	CSEL, L_{CE}	C-weighted sound energy integrated over an event.

Table 1c. Candidate Cumulative Noise Metrics

Metric	Abbreviation or Symbol	Origin/History
Hourly Noise Level	HNL	Defined by California airport noise regulation.
Equivalent Sound Level	L_{eq}, or $L_{eq(period)}$ if the particular averaging period is to be specified	Average noise level over a specified period, with averaging performed on an energy basis.
Day-Night Average Sound Level	DNL, L_{dn}	Energy average metric, with a nighttime penalty. Simplified heir to more elaborate metrics such as NEF, and to CNEL which has an evening penalty.
Community Noise Equivalent Level	CNEL	Defined by California airport noise regulation.
Weighted Equivalent Continuous Perceived Noise Level	WECPNL	Defined by ICAO for aircraft noise exposure.
Composite Noise Ratings - Community	CNR_C	Early (1952) community noise metric.
Composite Noise Ratings - Aircraft	CNR-A	Updated version of CNR_C, directed toward aircraft. Adjustments simplified, and a decibel scale used.
Noise Exposure Forecast	NEF	Energy average metric, with a nighttime penalty. Based on PNLT and EPNL.
Number-of-events Above	NA	Originated in Australia.
Time Above	TA	Originally part of FAA's Aircraft Sound Description System.
Time Audible	TAUD	Air tour intrusiveness in National Parks.
$L_{eq(16)}$	$L_{eq(16)}$	Used in UK.
Respite		Originating in Australia in 1990's; time interval between noticeable levels of aircraft noise at any receptor location is a period of respite (a measurable absence of aircraft noise).
Noise Pollution Level	NPL	Developed in late 60's/early 70's to improve upon Leq to account for variations in noise level over time.
Noise Rating Curves	NR	Octave band levels that provide ratings to be used in conjunction with Noise Criterion.
Rating Sound Level	L_r	A-weighted sound pressure levels that provide ratings to be used in conjunction with Noise Criterion.
Noise and Number Index	NNI	Originated from measurements and interviews surrounding Heathrow in 1960's.
Traffic Noise Index	TNI	Developed in the 1960's to measure the impact of traffic noise on a community.
Peak Noise Exceeded by 15 Percent of Firing Events	PK15(met)	Used for artillery fire and similar impulsive noises.
Onset-Rate Adjusted Monthly Day-Night Average Sound Level	L_{dnmr}	Originated for low-level military training routes.
EDNL/EDENL	EDNL/EDENL	Proposed by Kryter for interior perception of exterior noise.

Table 2. Scoring Criteria for Metrics

Criteria	Suitability for Aircraft Noise	Meaningfulness	Understandability	Ease of Calculation and Modeling
Rating/ Definition	*Having the appropriate attributes and properties to measure aircraft noise.*	*Having a definite purpose and value in the assessment of aircraft noise.*	*How well the public can grasp the effects of aircraft noise conveyed by this measure.*	*Degree of difficulty in including the metric in FAA's INM.*
3	High. Widely used and accepted.	High. Substantial supporting scientific evidence and widely used in official noise assessments.	Excellent. Uses commonplace terms of measurement making it easily understood.	Easy. No or little effort to include in INM.
2	Probable. Not widely used but functionally sound.	Moderate. Some supporting evidence and used in official noise assessments.	Good. Commonly used but not easily understood.	Manageable. Some effort at reasonable cost.
1	Unknown. Never been used but nothing functionally incompatible.	Marginal. Some supporting evidence but not used.	Satisfactory. Used but difficult concept to grasp.	Difficult. Can be done but at substantial cost.
0	Unsuitable. Functionally incompatible.	Meaningless. No supporting evidence and never used.	Poor. Too difficult to grasp due to overly complex measure with highly scientific terminology.	Impractical. Technical complex and significant data requirements.

Table 3a. Scoring of Candidate Level Metrics

Metric	Suitability for Aircraft Noise	Meaningfulness	Understandability	Ease of Calculation and Modeling	Total	#Votes	Initial Screening Summary
Sound Pressure Level (A-weighted)	3.00	2.67	2.17	3.00	10.83	23	Best level metric - substantial analysis led to it being preferred.
Perceived Level	2.17	2.00	1.33	1.20	6.70	23	Applicable over a wider range of sounds than just aircraft noise.
Perceived Noise Level	2.50	2.33	1.33	2.40	8.57	23	Developed for noise from early jets. Not enough better than A-weighting to be worth using. Remains in place for certification.
Tone Corrected Perceived Noise Level	2.67	2.33	1.50	2.40	8.90	23	Tone correction not needed for most current aircraft, but must not be forgotten if technology changes. Still in place for certification.
Articulation Index	1.50	1.50	0.67	0.60	4.27	23	Might be relevant where speech intelligibility is significant. But even the ANSI classroom standard uses A-weighting.
Speech Interference Level	1.83	1.33	1.17	1.00	5.33	23	Same position as AI
Sound quality indices (roughness, time varying loudness, etc.)	0.50	0.00	0.00	0.00	0.50	8	Not likely, but recent research deserves some consideration.

Table 3b. Scoring of Candidate Single Event Metrics

Metric	Suitability for Aircraft Noise	Meaningfulness	Understandability	Ease of Calculation and Modeling	Total	#Votes	Initial Screening Summary
Effective Perceived Noise Level	2.67	2.50	1.33	2.20	8.70	23	Relevant, but being PNL-based it remains in place for certification.
Sound Exposure Level	2.83	2.50	1.33	2.60	9.27	23	Appropriate equal-energy event metric, based on equal-energy.

Table 3c. Scoring of Candidate Cumulative Noise Metrics

Metric	Suitability for Aircraft Noise	Meaningfulness	Understandability	Ease of Calculation and Modeling	Total	#Votes	Initial Screening Summary
Noise Exposure Forecast	2.20	2.20	1.20	3.00	8.60	19	Still in use but functionally equivalent to DNL.
Number of Events Above	2.60	2.00	2.83	2.20	9.63	22	Quantifies an issue that is, anecdotally, considered to be important to the public.
Time Above	2.40	1.83	2.33	2.20	8.77	22	Alternate Metric in use.
Leq(16)	2.75	2.50	1.75	3.00	10.00	15	Daytime part of DNL.
Respite	1.20	1.40	2.20	1.20	6.00	20	Relevant as an alternative to DNL. Similar to "Noise Free Interval" considered for parks.
Noise and Number Index	2.20	2.40	1.60	1.33	7.53	18	Cumulative summation is not equal energy - important alternative to consider.
Isopsophic Index	2.00	1.50	1.00	1.00	5.50	8	CNR/NEF/DNL variant.
Mean Annoyance Level	2.00	1.00	0.00	1.00	4.00	5	Cumulative effect not equal energy
Noisiness Index	2.00	1.00	1.00	0.50	4.50	5	NEF-like
Total Noise Load	1.00	1.00	0.00	0.50	2.50	6	Time of day adjustments, and non-equal energy of interest.

Table 4. Relevant Aircraft Noise Metrics

Level Metrics	L_A, PNL, PNLT Sound quality, AI, SIL have some relevance
Single Event Metrics	SEL EPNL if PNLT matters
Cumulative Metrics	DNL, CNEL L_{eq}, $L_{eq(16)}$, HNL – for time of day variations NNI – alternate number summation WECPNL, B, EDNL/EDENL – elements of interest NA, TA, Respite – non-energy concepts, supplemental candidates L_{Amax10}

3.2 Non-Acoustic Factors

A list of non-acoustic factors was compiled. This list was based on review of the following reports:

- EPA Report No. 550/9–74–004, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety." (EPA Levels Document) (Reference 6).
- LVNL, Air Traffic Control the Netherlands, Report D/R&D 07/260 version 1.0, "Noise Annoyance Mitigation at Airports by Non-Acoustic Measures" (Reference 18).
- Fields, J., "Effect of personal and situational variables on noise annoyance in residential areas," *J. Acoust. Soc. Am.* Vol. 93 (5), May 1993 (Reference 19).
- Wyle Report 70-03, "Supporting Information for the Adopted Noise Regulations for California Airports," 1971 (Reference 7).
- Wyle Report EPA-NTID 300.3, "Community Noise.," December 1971 (Reference 20)
- Flindell, I.H., Stallen, P.M., "Non-acoustical factors in environmental noise," *Noise Health*, 1:11-6, 1999 (Reference 22).

The identified factors were categorized as either first or second order, and are listed in Table 5. First order non-acoustic factors are those which, following the literature review, were commonly cited as either being a notable concern of previous studies or surveys, or those which previous surveys attempted to correlate. Second order factors are those which were considered less often in the literature. It should be noted that overlap is present.

Historically, fear and misfeasance were significant non-acoustical considerations.[6] Further studies attempted to isolate the effects of non-acoustic factors on response, often with contradictory results. Fields[19] could not identify a strong correlation between income and annoyance, while the more recent ANASE[21] study did. In Reference 18 fear is classified as an intermediate factor, while Fields identified it as having an important effect. These contradictions may be associated with changes in attitude over the years. The Levels Document and Fields's research included studies before 1992, while References 18 and 21 represented more recent surveys. More recent surveys listed in the updated Catalog[9] have been reviewed to down-select Table 4 to factors that are relevant today.

Table 5. Non-Acoustical Factors

First Order	Second Order
Fear of noise source	Avoidability
Preventability	Choice in compensation (societal)
Sensitivity to noise	Expectations regarding future of source
Change in noise environment	Information (accessibility and transparency)
Attitude towards Source	Predictability of noise situation
Choice in insulation	Procedural fairness
Choice in compensation (personal)	Duration of residency near airport
Influence, voice	Fear related to source of noise
Perceived Control	Home ownership (fear of devaluation)
Recognition of concern	Use of airport services
Trust	Benefits from airport (personal, society)
Past experience with source	Cross cultural differences
Individual sensitivity to noise	Country of origin
Perceived predictability	Media Coverage and heightened awareness to noise
Income	Social status
Age	Age (above 55)
Understanding	Awareness of negative consequences (health, learning)
General attitudes	Children
Personal benefits	Education
Compensation	
Home ownership	
Accessibility to information	

Intentionally left blank.

SECTION 4 Review of Social Surveys

Reference 9 is a comprehensive catalog of social surveys on the response of residents to noise. It lists 628 surveys, conducted from 1943 through 2008, whose results have been published in the English language. The objective of the current study is to determine whether improvements or supplements to DNL can be made from data in those studies, or if not then what additional data is required.

4.1 General Considerations

The idea of a social survey is simple. Residents are asked questions about their satisfaction/dissatisfaction with noise, and the noise they are exposed to is measured or modeled. A statistical fit then gives a dose-response relation, represented earlier as Equation (1). There are two key elements in the relation. One is the input parameter, *M*. The other is the functional form and the quantity represented by the function *f*. The power of Schultz's seminal work was that he was able to represent different noise metrics in various surveys as DNL, and was able to interpret all of their outputs as percent highly annoyed, thus obtaining a single curve. In the years since then survey technology has improved so that merging of data requires fewer assumptions than Schultz needed. A substantial advance was the development of standardized survey question wording.[23] The particular questions asked still vary from survey to survey, as do the design of population and noise exposure samples, but the structure and wording presented in Reference 23 provide consistency and also permit merging of data from surveys in nine languages.

Accommodation of updates can address either the input *M* or the function itself. Adjustments defined in ANSI Standard S12.9 Part 4[24] permit effects not accounted for in DNL to be used as equivalencies, and the corresponding "*M*" (which is no longer formally DNL) is inserted into the *f* that corresponds to the Schultz curve.

An example of the alternate method, modifying *f*, is the Community Tolerance Index (CTI)[25] developed to quantify the non-acoustic contribution to annoyance. The concept is based on the assumption that the prevalence of annoyance grows at the same rate as duration-corrected loudness of noise exposure, and that the Day-Night Average Sound Level (DNL) is an expedient estimate of duration-corrected loudness. The resulting curve is then adjusted for best fit to a particular set of survey response data. The CTI is arbitrarily defined as the DNL value at which 50% of respondents are highly annoyed by noise exposure, and represents the tolerance of the surveyed community to aircraft noise. While this specific analysis would be more attractive if there were an objective method of obtaining the parameter CTI, it is a good demonstration of mathematically accommodating a modifier as a change to *f*.

Whether an improved function is best represented by an adjustment to metrics or to the form of the response function *f*, derivation of a metric and response becomes a matter of functional fitting. Fitting can take place in a variety of forms. For analysis of the effect of time of day or other periods on response, Fields[26] wrote the linear fitting schematically as

$$A_{T_k} = a + B_I \cdot L_{I_k} + E_k \tag{2}$$

Where A_T is annoyance for period T, $(\ )_I$ is noise index, $(\ )_k$ is a person, and E represents errors. While this is written in linear form, it is easily generalized to nonlinear form by suitable mapping of either the input or output variables.

The coefficients *a* and *B* are obtained by fits to the data. Fields defined four methods of fitting:

1. Total regression – fit for total impact, determine coefficients and weights.
2. Index correlation – compare two models, see which is better.
3. Period response correlation – weights based on offsets between period results.
4. Respondent ranking – look for level difference when half think one period is worse than the other.

Method 1 is the most general, but at the time Fields's analysis was performed no survey had been analyzed that way. The other three methods have been used. Method 2 is the simplest, but it does not yield the coefficients. It just tests which of two pre-defined metrics performs better than the other. Much of fitting newer survey data to the Schultz curve could be considered to be Method 2, often without having a second metric to test against. Method 2 is valuable in that a supplemental metric chosen for non-acoustic reasons can be tested to see how well it might serve as a surrogate for a validated acoustic metric.

Another consideration for multivariate fitting is whether the independent variables are independent of each other. Fields[27] showed that at most airports daytime and nighttime operations are well correlated, making it very difficult (if at all possible) to separate the coefficients for those two periods. Using data available at that time, he was able to show that the noise at night caused more annoyance than during the day, but was only able to derive the night weighting as falling somewhere between 1 dB and 18 dB.[28]

The issue of correlation between different independent variables casts doubt on the tradition of trying to improve the Schultz curve by adding more survey data to it. Not all surveys are designed for that simplistic application. They are often designed to obtain results for one particular variable in the general multivariate space. Miedema et al.[29] were able support the traditional night weighting of 10 dB from survey data collected in an area where day and night operations were uncorrelated.

4.2 Review of Surveys

The utility of the 628 surveys cataloged in Reference 9 depends on several factors, including:

- Design, in terms of separating particular variables
- Quality of questionnaire and noise data, with newer surveys tending to benefit from the developed technology
- Availability of data.

Following development of the updated catalog,[9] Wyle was tasked with identification and preliminary evaluation of "high interest" surveys that could assist in the development of further research.[30] Reference 30 is included here as Appendix A.

Four types of high-interest surveys were identified. Each addresses annoyance within the scope of the criteria used to include surveys in the Catalog. Some research in each of these categories was initiated by Fields in previous work,[31,32] which formed a basis for the criteria and evaluation of this analysis. Publications and surveys in the updated 2008 Catalog were identified that address four categories of surveys:

- Surveys which include a number or level weighting;
- Surveys which analyze a dose/response relationship for aviation and other sources;
- Surveys which include a time of day weighting; and
- Surveys that have evaluated community response during different time periods at the same airport.

These four categories were denoted N (number of events), M (multiple sources), T (time of day) and D (different time periods), respectively.

The surveys were quantitatively reviewed for these factors, and scored hierarchally. The following scoring codes were used:

1. Full information available.
2. Some information available.
3. No information available.
4. Unable to determine what information is available.
5. Not addressed

Code 4 was used for foreign reports and for other long reports, where the content could not be readily determined on initial scanning. It is possible that additional information could be found from a more thorough review. The content that was searched for and scored was as follows:

Social survey information:

- Whether or not pretests were conducted of the survey instrument.
- How or why some study areas were selected or why some potential exposure areas were not eligible.
- How or why some dwellings were selected or why some dwellings in the study areas were not eligible.
- Were any types of inhabitants ineligible for the survey (for example age restrictions, etc.)?
- How were respondents chosen from within the eligible respondents in a dwelling?
- Whether any types of completed responses were excluded from the analysis.

Nominal noise environment:

Is the estimated noise environment associated with each respondent specified as to:

- The part of day or week that the estimate is assumed to represent.
- The length of time the estimate has been constructed to represent, i.e., previous year, month or longer period.
- The meteorological conditions that the estimate is assumed to represent.
- The nominal position at the respondent's dwelling. (For example, one meter from the noisiest facade with the effects of reflections from the facade removed).

Noise Modeling (if model-based noise estimation was involved):

- The name, specifications or algorithms for the model for the source noise emission.
- The source of data that were input to the model for this study's estimates for the source noise model.
- The name, specifications or algorithms for the model for noise propagation.
- The source of data that was input to the model for the estimates for this study's estimates for the propagation to the respondent's residence.

Noise Measurements (if site-specific measurement based elements were used):

- The type of instrumentation used.
- The measurement protocol followed for periods during which data were acquired.
- The method for sampling periods that were measured.

Judgment about completeness of information:

- Noise Exposure: The overall precision of the exposure for each respondent for the nominal condition and location.
- Number/level: The precision of the estimates for the purpose of estimating the number/level trade off. Special consideration was given to how numbers of events were counted and how the levels of those events were combined. Arbitrary cut points for counting events or selecting events to be average are often poorly defined or of doubtful relevance.

- Time-of-day: The precision of the estimates for the purpose of estimating the time-of-day weighting. Special consideration was directed at the methods for estimating the exposure in each time period and how the methods might affect the estimate of the time-of-day weighting.
- Ambient impact: The precision of the estimates for estimating the effects of ambient noise. (If the study used urban/rural as a proxy for ambient noise or ambient as a proxy for urban/rural, then this was also considered.) Besides more general considerations as to comparability of the measurements in the low and high ambient areas, special attention was directed to the nominal position for noise from surface-based transportation.
- Airport annoyance changes: The precision of the estimate of changes in aircraft noise exposure. Of special concern here is the consistency in the noise estimation procedures and the social survey methods between the different years.

Published conclusion: The basic topic-specific conclusion for each high-interest topic

- Number/level: What is the estimated number/level weighting?
- Time of day: What is the estimated time of-day weighting penalty for-each time period?
- Ambient impact: Do low ambient noise levels increase, decrease or not affect annoyance with a target noise?
- Airport annoyance changes: Has annoyance, controlled for noise level, increased, decreased or stayed the same over time?

Of the 628 surveys in the catalog, somewhat over 50 published after 1982 were identified as appearing to have collected sufficient data that could be used to conduct analyses of numbers of events, time-of-day effects, different noise sources, ambient noise effects, and discrete changes in noise exposure over time. With the variety of designs, these were separated into those that appeared to be suitable for analysis of coefficients for number of events, time of day, multiple sources, and differences over time. Table 6 lists the surveys, with a code denoting the type (N, M, T, D), the catalog number, and the title. Some surveys appear in more than one category, and in one instance multiple parts of a multi-national survey were grouped together.

Each of these was scored according to the numeric codes listed above. These scores established the utility of the survey. For the current purpose of examining metrics, N (number of events) and T (time of day) surveys are of direct interest. Table 7 presents the surveys and scores for these two categories, with "T" surveys in part a and "N" surveys in part b. The scoring codes are repeated under each table.

Table 6. High Interest Surveys

ID	CATALOG	TITLE
N1	USA-338	1981 USA Air Force Base Study
N2	SWE-228	1978-80 Swedish Railway Study
N3	SWE-359	Gothenburg 12-Area Traffic Noise Survey
N4	UKD-242	1980 Heathrow Noise Index Trial Survey
N4	UKD-008	1961 Heathrow Aircraft Noise Survey (First Heathrow Survey)
N5	SWE-419	1988-93 Swedish Small Airport Noise Survey
N6	AUL-210	1980 Australian Five Airport Survey
N7	USA-235	1983 Controlled Exposure Helicopter Noise Study
N8	BEL-288	1980s Brussels International Airport Noise Survey
N9	UKD-225	1982 United Kingdom Aircraft Noise Index Study
N10	UKD-324	1986 English General Aviation Survey
N12	JPN-541	2001 Sapporo Hokkaido Railway Noise Survey
N13	UKD-604	2005 Attitudes to Noise from Aviation Sources in England (ANASE)
T1	AUL-210	1980 Australian Five-Airport Survey
T2	USA-219	1980 Salt Lake City In-Home Aircraft Rating Study
T3	UKD-309	1977 Hamble Airfield Survey
T4	UKD-243	1981 United Kingdom General Aviation Airport Survey
T5	FRA-197	1979 French Behavioral Effects of Road Noise Study
T6	FRA-364	1993-94 French 18-Site Time-Of-Day Study
T7	USA-170	1978 U.S. Army Impulse Noise Survey
T8	AUL-589	2005-2006 Australia Nighttime Truck Noise Longitudinal Survey
T9	SWI-534	2003 Zurich-Kloten Aircraft Noise Survey
T10	NET-371	2002 Amsterdam Schiphol Airport Noise and Health Survey
T11	GER-532	2004 German Time of Day Annoyance Survey and Diary
T12	GER-531	2005 Frankfurt Airport New Runway Annoyance Survey
M1	UKD-567	2003 HYENA (Hypertension and Exposure to Noise near Airports) Study
M2	SWI-525	2001 Swiss Zurich-Kloten Aircraft Noise Study
M3	SWE-228	1978-80 Swedish Railway Study
M4	UKD-241	1982 Heathrow Combined Aircraft/Road Traffic Survey
M4	UKD-238	1984 Glasgow Combined Aircraft/Road Traffic Survey
M5	AUL-307	1986 Sydney Aircraft/Road Traffic Survey
M6	AUL-383	1994-95 Sydney Airport Noise Change Survey
M6	AUL-210	1980 Australian Five-Airport Survey
M7	AUL-307	1986 Sydney Aircraft/Road Traffic Survey
M8	CAN-168	1978 Canadian Four-Airport Survey
M9	KOR-554	2004 Korea Airport and Background Noise Survey
M10	KOR-590	2005 Gimpo International Airport Annoyance Survey
M11	SPA-571, UKD-610, NET-575	2002 RANCH Children’s Road Traffic and Airport Noise Health Survey (Schiphol, Heathrow, Barajas)
D1	USA-301	1982 Westchester Airport Nighttime Noise Change Study
D2	NOR-311	1989 Oslo Airport Survey
D3	NET-361	1993 Netherlands National Environmental Survey
D4	CAN-168	1978 Canadian Four-Airport Survey
D5	JPN-509	1972-81 Kyushu Airport Opening Survey
D6	GER-363	1988 German Noise Barrier Evaluation Survey
D6	GER-373	1987 Düsseldorf/Ratingen Aircraft/ Road Traffic Survey
D7	USA-203	1978-79 Time-of-Day Study with Annoyance Recording Device
D7	USA-203	1979 Burbank Aircraft Noise Change Study
D7	USA-206	1981 Alabama Three-Site Blast Noise Survey
D8	USA-027	1968 LAX Aircraft Noise Study
D9	USA-082	1973 Los Angeles Airport Night Study
D10	NOR-328	1992-93 Bodö Aircraft Military Exercise Survey
D11	AUL-383	1994-95 Sydney Airport Noise Change Survey
D11	AUL-210	1980 Australian Five-Airport Survey
D11	AUL-383	1994-95 Sydney Airport Noise Change Survey
D12	USA-431	1995 Seattle-Tacoma Airport Noise Survey
D13	CAN-385	1990s Vancouver Airport Noise Change Survey
D14	JPN-551	2005 Japan Narita Airport Noise Effects
D15	NET-533	2002 Netherlands Amsterdam Schiphol Airport Noise and Health Survey
D16	SWI-525	2001 Swiss Zurich-Kloten Aircraft Noise Study
D16	SWI-534	2003 Zurich-Kloten Aircraft Noise Survey
D17	NOR-752	1998-99 Oslo Aircraft Change

Table 7a. High Interest Surveys with Emphasis on Time of Day

	Survey											
	AUL-210	USA-219	UKD-309	UKD-243	FRA-197	FRA-364	USA-170	AUL-589	SWI-534	NET-371	GER-583	GER-531
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
SURVEY ELEMENTS												
SOCIAL SURVEY												
Questionnaire	1	1	1	1	1	2	1	2	2	2	2	2
Pretests Conducted	1	1	3	3	1	3	2	3	3	3	3	2
Study Area Selection Criteria	1	1	1	2	2	2	1	1	1	1	2	2
Dwelling Selection Criteria	1	1	1	2	2	3	1	1	2	3	3	2
Inhabitant Restrictions	1	1	3	2	3	3	1	2	1	3	3	2
Respondent Selection within Dwelling	1	1	1	2	3	3	1	3	2	3	3	2
Respondent Exclusions	1	1	3	2	3	3	1	3	1	3	3	2
NOISE ENVIRONMENT												
Noise - Time	2	1	-	2	1	2	3	3	1	1	1	2
Noise - Period	1	1	-	1	1	2	1	3	1	1	1	1
Met. Conditions	4	4	4	4	3	3	3	3	3	-	5	-
Respondent Location	4	1	-	2	1	3	3	3	3	1	3	1
NOISE MODELING												
Noise Model	3	-	1	-	-	1	2	3	1	1	1	1
Input Data Source	2	-	1	-	-	3	1	3	1	3	2	2
NOISE MEASUREMENTS												
Instrumentation	3	2	3	1	2	3	1	3	-	-	-	-
Measurement Protocol	2	2	3	2	2	3	2	3	-	-	-	-
Method of Sampling	2	1	3	2	2	3	2	3	-	-	-	-
JUDGEMENT OF COMPLETENESS												
Noise Exposure	2	1	2	1	2	2	2	3	1	2	2	2
Number/Level	5	5	4	2	5	5	2	5	5	5	5	5
Time-of-Day	1	1	2	2	1	2	1	1	1	1	2	2
Ambient Impact	5	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	2	5	5	5	1	1	2	5	5
PUBLISHED CONCLUSION												
Number/Level Weighting	5	5	4	2	5	5	2	5	5	5	5	5
Time of Day	1	1	2	2	2	2	1	5	1	1	2	2
Ambient Impact	5	2	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	2	5	5	5	1	2	2	5	5

Scoring codes:

1. Full information is available in document
2. Some information available in document; full information is probably available
3. No information available in document; full information is probably available
4. Unable to determine what information is available
5. Not addressed

Table 7b. High Interest Surveys with Emphasis on Numbers of Events

	Survey											
	USA-338	SWE-228	SWE-359	UKD-242	SWE-419	AUL-210	USA-235	BEL-288	UKD-225	UKD-324	JPN-541	UKD-604
	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N12	N13
SURVEY ELEMENTS												
SOCIAL SURVEY												
Questionnaire	2	3	3	1	2	1	1	2	1	1	1	1
Pretests Conducted	4	4	3	1	4	3	1	3	1	3	3	1
Study Area Selection Criteria	2	2	2	1	2	2	1	2	1	1	2	1
Dwelling Selection Criteria	2	2	2	1	3	2	1	3	1	1	2	1
Inhabitant Restrictions	4	1	1	1	2	2	1	3	1	1	1	1
Respondent Selection within Dwelling	4	3	1	1	4	2	1	3	1	1	1	1
Respondent Exclusions	3	1	1	1	3	2	1	3	1	1	2	1
NOISE ENVIRONMENT												
Noise - Time	3	1	1	1	3	1	1	1	1	1	3	2
Noise - Period	1	4	1	1	3	1	1	1	1	1	1	2
Met. Conditions	4	4	3	3	3	5	3	5	3	3	3	3
Respondent Location	4	4	3	1	3	4	2	5	1	2	2	2
NOISE MODELING												
Noise Model	-	-	-	-	-	3	-	-	-	-	3	1
Input Data Source	-	-	-	-	-	3	-	-	-	-	3	1
NOISE MEASUREMENTS												
Instrumentation	2	4	2	3	3	3	3	1	1	3	3	2
Measurement Protocol	4	4	2	1	3	2	3	3	1	2	2	2
Method of Sampling	4	4	2	1	3	2	2	3	1	2	2	2
JUDGEMENT OF COMPLETENESS												
Noise Exposure	2	2	2	1	2	1	2	2	1	1	2	1
Number/Level	2	2	1	1	2	1	1	2	2	2	2	1
Time-of-Day	2	5	5	1	5	5	5	2	2	5	3	5
Ambient Impact	5	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	3	5	5	5	5	5	5	5	5
PUBLISHED CONCLUSION												
Number/Level Weighting	2	1	1	1	1	1	1	2	3	3	2	1
Time of Day	4	5	5	1	5	5	5	2	3	5	3	5
Ambient Impact	5	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	3	5	5	5	5	5	5	5	5

Scoring codes:

1. Full information is available in document
2. Some information available in document; full information is probably available
3. No information available in document; full information is probably available
4. Unable to determine what information is available
5. Not addressed

4.3 Review of Surveys for Noise Effects, Metrics and Data

In the context of noise impact being a multivariate function, Equation (1), it is important to recognize separation of variables, as discussed in Section 4.1, and also the resolution associated with different types of studies as discussed in Section 2. It is also prudent to focus the analysis on aviation noise, rather than attempt to seek global results for all types of noise. Aviation noise does have particular characteristics, for which extrapolation from non-aviation sources may not be relevant. These are spectral content, duration of events, and discrete events, and are reflected in the first two categories listed in Tables 1 and 4.

As discussed earlier, PNL was developed for aircraft noise, and was based on laboratory studies of human hearing response.[33] In the 1970s the general adoption of A-weighting was made possible by a good correlation between L_A and PNL for aircraft of that era. Kryter has recently pointed out that spectral differences can still matter, and may be responsible for the difference in community response to different noise sources.[34]

While level is the primary measure of loudness, the significance of tonality when present has been reaffirmed in recent FAA sponsored research.[35] Other candidate effects, such as roughness, were shown to be of tertiary importance. These effects were developed in laboratory studies, and the quantitative results suggest that (within spectra typical of aircraft) only tonality is of practical significance. To affirm the significance of tonality in a social survey would require a setting with aircraft with and without distinct tonal characteristics, much as night weighting was successfully measured in Reference 29 at a location with areas of uncorrelated day and night operations.

The equal-energy relation between level and duration, for durations typical of aircraft noise events as shown in Figure 4, is so well supported that there is little reason to seek variations. Maximum level is sometimes used instead of SEL, but that apparently is successful where durations are consistent so that L_{max} and SEL are correlated. Analysis of non-aircraft noise environments would represent a domain not relevant to aircraft noise.

With those considerations, the review of social surveys has been limited to those that involved only aircraft noise. For "T" surveys, those are T1, T2, T3, T4, T9, T10 and T12. For "N" surveys, those are N1, N4, N5, N6, N7, N8, N9, N10 and N13. N7, N9 and N10 have some interest for spectral effects because they focused on helicopters or General Aviation aircraft rather than conventional commercial airliners. T1 and N6 are the same survey (AUL-210) so there are 15 surveys of direct interest. These have been reviewed for the following:

Availability of noise data, with regard to ability to compute metrics of the general form

$$A = B_0 + B_L L + B_N \log_{10} N \qquad (3)$$

where different values of B_i may apply to different times of day

- The ability to compute from available noise data, metrics such as NA, TA and L_{Amax10}.
- Which direct noise effects are addressed in the questionnaire. The effects generally include those listed in Section 1.2:
    - Speech interference
    - Sleep disturbance
    - Task interference
    - Impairment of classroom learning
    - Non-auditory health effects
    - Aversive effects on emotion and tranquility
- Availability of the survey response data

Table 7 lists those details for each of the 15 surveys of interest.

Table 8. Relevant Details of 15 Surveys of Interest

Survey	Details
T1,N6 AUL-210 Australian five-airport study	Data for Equation (3) are included. Numbers of events and time of day data are available. Conclusions are drawn regarding both. Metrics of interest - including DNL, LX10% (equivalent to L_{Amax10}), numbers of events - are presented. Direct effects of speech interference, task interference, sleep disturbance are included in questionnaire. Personal, demographic, and attitudinal non-acoustic factors were surveyed. Does not address impairment of learning or non-auditory health effects. Because the survey was conducted in 1980, aircraft types are Stage 1 and Stage 2. Original project report and follow-ups contain analyses in terms of the factors and metrics. Reaction is quantified by "General Response" (GR) rather than Schultz's percent highly annoyed.
T2 USA-219 1980 Salt Lake City In-Home Aircraft Rating Study	Single event listening experiment, in homes but closer to laboratory study than social survey. Addressed level and event metrics, and time of day. Did not address cumulative metrics (Equation (3) or others). Addressed ambient levels, and found that when adjustments were made for ambient the time of day did not correlate with annoyance. Times included morning, afternoon and evening periods, but not night. The estimated effect of six personal variables are presented but are acknowledged as imprecise: Age, gender, hearing, home ownership, length of residence.
T3 UKD-309 1977 Hamble Airfield Survey	GA piston engine aircraft. 445 interviews in six districts. Full questionnaire included. Initial survey asked about attitude towards living environment without mention of noise. Survey included rating of fear of aircraft crashes, general attitude towards the airport, employment at airport, other general demographic data. Direct effects addressed were: makes the TV picture flicker; interferes with listening to radio or TV; keeps from going to sleep. Noise calculated for a different time period than the survey was conducted, then scaled. Operations data not available. More than 90% of respondents were exposed to L_{eq} < 55 dB.
T4 UKD-243 1981 United Kingdom General Aviation Airport Survey	Survey around five GA airports in 1981. Full questionnaire included. Time of day questions were day, evening, night. Some responses about weekend versus during the week. Various direct and indirect disturbances reported. Noise determined by automatic digital noise monitors, with events matched to airfield movements. NNI, L_{eq} (12 hour day), PNdB presented for the study areas, 0600-1800. Evening noise (1800-2200) also presented. Operations data not included in report. Conclusions generally supported NNI.

Table 8. Relevant Details of 15 Surveys of Interest (*continued*)

Survey	Details
T9 SWI-534 2003 Zurich-Kloten Aircraft Noise Survey	Along with SWI-525, surveys in 2001 and 2003 around Zurich-Kloten airport. Change in operations provided opportunity to assess time of day effects associated with shoulder hours. Survey questionnaire is available, in German, and included non-acoustical factors such as age. Further, the study evaluated the potential influence of noise awareness associated with a step-change in noise exposure. Generally followed ICBEN protocol. Noise modeled in detail with FLULA2 simulation model. Noise metrics concentrated on L_{den}, daily L_{eq}, and hourly L_{eq}. By the nature of FLULA analysis, any temporal metric could be recomputed, as well as cumulative metrics of the form of Equation (3).
T10 NET-371 2002 Amsterdam Schiphol Airport Noise and Health Survey	1996 to 1997 survey at Schiphol airport. 11812 surveys. Effects addressed were annoyance, sleep disturbance, perceived health, use of medication, and quality of life. Study area included locations where day and night operations were uncorrelated, so that night factors could be deduced. Non-acoustic factors included age, sex, education, household size, home ownership, dependency on the airport, use of airport, sensitivity to noise, and fear. Data is probably available, and could be used to compute Equation (3) metrics and others. Questionnaire and response data are not in the document, but probably available.
T12 GER-531 2005 Frankfurt Airport New Runway Annoyance Survey	2005 study associated with a new runway at Frankfurt Airport. 2312 face to face interviews were conducted. The questionnaire was based on prior studies and used standardized scales. Variables included demographic information, sensitivity to environmental stressors, quality of life, health effects, and sleep. A subsample of 200 people were assessed every hour. Noise was modeled by the German "AzB" procedure. Metrics reported included L_{den}, L_{tan} (an L_{den} variation with different day-evening-night periods), L_{dn}, L_{max}, and NA. Noise data are sufficient to compute Equation (3) metrics and others of interest.
N1 USA-338 US Air Force Base Study	942 face to face interviews at seven Air Force Bases, in 1981/1982. Planned as an indirect approach to understand how individuals integrate varying noise exposure over time. Noise monitors deployed for about 10 days. For every event above 65 to 70 dB, the monitor recorded L_{max}, time of maximum, 10 dB down duration, and SEL. HNL, 24 hour L_{eq} and L_{dn} were computed. Aircraft events were separated from others by examining levels, durations and times. Interviews included questions on activity interference and annoyance. In addition to interference with activities that included communication, sleep, rest and TV viewing, nine non-acoustic variables were included. Those were ranked in order of correlation between annoyance and personal variables. They include Fear of crashes, Harmful Health Effects, Readiness to Complain, Misfeasance, Length of Residence, Relatives at Base, Noise Sensitivity, Income, General Satisfaction with Neighborhood. Responses were correlated with actual events heard. The best predictor of annoyance was found to be a multiple correlation of the highest number of flights by L_{max}, by day , evening and night periods. The second best predictor was the average number of flights, by L_{max} and time period. Single metrics like DNL were less effective.

Table 8. Relevant Details of 15 Surveys of Interest (*continued*)

Survey	Details
N4 UKD-242 1982 United Kingdom Aircraft Noise Index Study (Supported by UKD-241, Heathrow Combined Aircraft/Road Traffic Survey)	Known as ANIS (Aircraft Noise Index Study) this survey of 2097 residents around five airports in the UK was conducted to assess NNI which had been in use. It concluded that L_{eq} provided a better weighting for number of events. The questionnaire addressed annoyance in three time periods: day (0700-1900), evening (1900-2300) and night (2300-0700). Activity interference questions included interference with listening to radio, TV or hi-fi; house shaking; interference with conversation; awakening from sleep; other activities. Included demographic variables such as class, age, gender, marital status, among others. The study determined that people who work or have business at the airport report markedly lower annoyance ratings. The survey questions are available. Noise measurements were conducted at a site within each cluster of surveyed residents. The measurements accounted for individual events, and cumulative metrics were computed from those.
N5 SWE-419 1988-93 Swedish Small Airport Survey	1988-1993 surveys at three small and medium airports. 513 subjects. The questionnaire asked about general satisfaction with the living area, and about annoyances from different sources in the environment. A good correlation was found between annoyance and numbers of events above 70 dB. The questionnaire and noise measurement details are not in the paper.
N7 USA-235 1983 Controlled Exposure Helicopter Noise Study	338 people were interviewed a total of 6345 times about their reaction to helicopter noise. The initial interview was face to face, and follow-ups by telephone on up to 22 additional days. Helicopter operations from 1 to 32 per day, 9AM to 5PM, were scheduled during the study period. A good correlation with number of events, supporting equal energy, was found. Two types of helicopters were involved, with the sound from one being more impulsive than the other, and differences in reaction were noted. The study concluded that demographic variable effects were small and statistically insignificant. No correlation was found between employment at the military facility. Attitudinal variables, including fear, preventability, and satisfaction with the sound environment of the neighborhood were considered. Data for this study should be available.
N8 BEL-288 1980s Brussels International Airport Noise Survey	677 residents surveyed in1980, 1984 and 1985, at 11 locations around Brussels. A questionnaire (not published but probably available) with 21 questions was administered. Noise measurements were made with digital community noise analyzers, capturing individual flight events. The analysis was performed for NNI, FBI, QB and TA at several thresholds. Social variables in the analysis included interference with conversations, watching TV, hobby activities, sleep, and general global impression. Included rural areas, and general demographic variables were collected.
N9 UKD-225 1982 British Helicopter Disturbance Study	1982 survey of noise from helicopters in five areas, with 438 participants. Good noise measurements were made, and the survey questions were included in the report. Correlations were evaluated for age, sex, time in residence, marital status, workplace status, and fear. This study appeared worth following up, but a request for the data and further information was fruitless.

Table 8. Relevant Details of 15 Surveys of Interest (*concluded*)

Survey	Details
N10 UKD-324 1986 English General Aviation Survey	390 residents surveyed in 1986 around five GA airports. GA airports were noted to be different from commercial airports due to the presence of piston engine propeller aircraft (often single engine) and repeated circuit patterns. Noise measurements were made using attended and unattended systems, with the objective of obtaining enough single event records so as to compute a variety of metrics. The questionnaire is included, together with summary tables of noise and social survey results. Socio-psychological variables (opinion of area, knowledge of aircraft operations, non-noise aspects of flying) and demographic variables were considered. This study used a multivariate annoyance model, addressing both noise and socio-psychological variables. It was found that annoyance was influenced more by socio-psychological reactions and socio-economic conditions than by noise.
N13 UKD-604 Attitudes to Noise from Aviation Sources in England (ANASE)	Face-to-face interviews of 2132 residents around UK's 20 busiest airports. Conducted in 2005-2006. The study's objectives were to re-assess attitudes toward aircraft noise, and re-assess the correlation with the L_{eq} noise index that had been adopted after ANIS (UKD-242). The study examined hypothetical willingness to pay for relief from noise. Valuation was assessed by stated preference (SP) methods. A more direct contingent valuation item was also included in the survey. Demographic variables, including income level and whether the respondent worked at the airport, were collected. The survey instrument is included in the published report. Noise measurements were conducted at 19 of the 20 study areas, in sufficient detail to estimate sound exposure for each respondent. Noise calculations were performed with INM v6.2. Air Traffic Control data were used as inputs, and monitoring data collected as part of the study was used to calibrate the modeled results. The main study was preceded by a series of pilot studies to assess particular details and methods. The pilots included determining "discriminable factors" such as aircraft type, numbers, and time of day/night; noise monitoring techniques including potential value of indoor monitors; annoyance in very low noise areas; the workability of details of the SP method; alternate ways of presenting noise options; and methods of presenting noise. Analysis of metrics focused on the effect of numbers of events.

Table 9 presents capsule summaries of the suitability of each of these surveys for the purpose of updating or supplementing DNL. The summary conclusion is in the rightmost column, with a recommendation about whether data and further analysis should be pursued. Seven studies are judged to not be candidates, either because they are not comprehensive enough or because it is known that data are not available.

Two studies (UKD-604 and UKD-324) are judged suitable and relevant. UKD-324 is relevant because of its successful multivariate analysis approach. UKD-604 is of substantial interest because of its special approach and extensive scope, as well as being recent and representing modern aircraft. UKD-242 is also relevant in that it is a baseline against which UKD-604 can be compared. As noted in Table 9, data from UKD-604 have been requested for use in DoD noise metric studies.

Five surveys are listed as "Maybe". Three (SWI-534, NET-371 and GER-531) are recent (circa 2000 or later) surveys conducted in Europe that build very well on the lessons learned from earlier pre-1980s surveys, It is not known if data can be obtained, and language may be an issue, but there is potential for metric analysis. One (BEL-288) is older, but contains a good range of non-acoustic variables and noise data that can be analyzed for various metrics. The last (USA-338) is a study conducted in the United States in the early 1980s that has high quality detailed noise data and a very good range of non-acoustic factors, as well as the usual annoyance and interference variables. There is a possibility that data may be available, and a request has been made.

Table 9. Synopsis of Suitability of Surveys of Interest

Survey	Potential for Further Analysis	Pursue?
T1,N6 AUL-210 Australian five-airport study	Excellent survey program. Analysis is thorough, addresses multiple metrics, and provides one set of answers to issues here. The age of the survey and depth of analysis lowers the probability of useful re-analysis. Not a candidate, but valuable prior art.	No
T2 USA-219 1980 Salt Lake City In Home Aircraft Rating Study	Does not address cumulative metrics.	No
T3 UKD-309 1977 Hamble Airfield Survey	Noise calculations not coordinated with survey. Not a candidate.	No
T4 UKD-243 1981 United Kingdom General Aviation Airport Survey	Possible re-analysis if original noise recordings are available. Low probability because of age of survey.	No
T9 SWI-534 2003 Zurich-Kloten Aircraft Noise Survey	With the earlier SWI-525, this is a very good modern-technology survey with excellent noise modeling. Good potential for analysis of other metrics. Questionnaire not in English.	Maybe
T10 NET-371 2002 Amsterdam Schiphol Airport Noise and Health Survey	Good study with modern methodology and a large number of responses. Regions of uncorrelated day and night operations, providing a good opportunity for time of day analysis.	Maybe
T12 GER-531 2005 Frankfurt Airport New Runway Annoyance Survey	Good study with noise calculated from a model. If model data are available, and translation of the questionnaire into English is feasible, this is a possibility for further analysis.	Maybe
N1 USA-338 US Air Force Base Study	This study is of particular interest because of the detailed noise measurement, the questions about non-acoustic factors, and the "non-DNL" approach. Although it is old, and was based on military aircraft in the early 1980s, the level of detail is very good. The Air Force Research Laboratory personnel mentioned in Borsky's report have a reputation for archiving data, so the data may be available.	Maybe
N4 UKD-242 1982 United Kingdom Aircraft Noise Index Study ((Supported by UKD-241, Heathrow Combined Aircraft/Road Traffic Survey))	This was a good study, with questions published and noise data collected. Data availability is questionable. Requests for data from related studies by the same organization were not fruitful. Known as ANIS, some data were re-analyzed as part of ANASE (UKD-604) and might be available as part of that data.	If bundled with ANASE
N5 SWE-419 1988-93 Swedish Small Airport Survey	This study showed that, for the small airports studied, annoyance correlated well with number of events. Because of the limited scope of the questionnaire, it is not likely that more general relations could be extracted.	No
N7 USA-235 1983 Controlled Exposure Helicopter Noise Study	This was a well done study that supported equal energy summation of events. While differences in reaction between the two helicopter types were noted, there was no comparison with other noise sources. As a NASA study the data should still be available, but this was too specialized for general re-analysis.	No
N8 BEL-288 1980s Brussels International Airport Noise Survey	Very good noise measurements. Relatively small sample, and also 1980s vintage aircraft. Depending on the actual questions in the survey and the availability of data, this has potential for further analysis.	Maybe

Table 9. Synopsis of Suitability of Surveys of Interest (*concluded*)

Survey	Potential for Further Analysis	Pursue?
N9 UKD-225 British Helicopter Disturbance Study	Good study, although small and long ago. Data not available.	No
N10 UKD-324 1986 English General Aviation Survey	Distinctive in that a multivariate annoyance model was used, and that non-acoustic factors were found to be more significant than noise. Valuable as a prior art of multivariate analysis of aircraft noise. Obtaining the original data would be useful for further development of that approach.	Yes
N13 UKD-604 Attitudes to Noise from Aviation Sources in England (ANASE)	This is a widespread study with good supporting noise data, and a unique approach that has substantial potential to understand non-acoustic factors. Data are currently in the process of being made available to Wyle for use in Department of Defense airbase noise metric studies.	Yes

Survey AUL-210 is denoted "No" not because of any shortcoming, but rather because it was so well analyzed that it is doubtful that further analysis would yield more information on top of the comprehensive results (including analysis of 20 metrics) that the original researchers obtained. It was conducted in Australia in the early 1980s, which makes specific results less relevant for modern aircraft in the United States. But it defines a successful experimental design and protocol, with metric analysis goals that coincide with the objectives of the current studies.

4.4 Survey Technology and Design

While conducting this review it has become clear that noise survey technology has evolved and improved over the decades. When Schultz published his synthesis[8] in 1978, it was impressive that consistency could be obtained. Schultz himself used the word "remarkable." In the 1980s, Fields addressed issues of analysis methods,[26] correlation of time periods,[27] etc. More recent surveys, e.g., Reference 29, have been designed to appropriately separate variables and obtain the particular data of interest.

The Community Oriented Solutions to Minimise aircraft noise Annoyance (COSMA)[36] project currently underway in Europe exploits this improved methodology. COSMA is intended to develop engineering criteria for aircraft design and operations in order to reduce aircraft annoyance in communities. The COSMA work plan includes field and laboratory studies. Preparation for the annoyance studies has been based on careful review of the prior studies, including re-analysis of data from the Frankfurt Noise Annoyance Study[37] (GER-531), in order to identify acoustical, operational and non-acoustical factors that contribute to short-term annoyance.[38] Field studies will include face-to-face and telephone interviews and experience studies at several major European airports, selected for a variety of size, day/night operations, and demographics. Part of the study will include a subset of subjects who will rate every individual flyover, and the actual time signals for those events will be recorded indoors and outdoors. The intention is to collect data with a degree of thoroughness such that engineering analysis can be performed to predict the benefits of changes in aircraft sound levels and qualities and in aircraft operations.

SECTION 5

Summary and Recommendations

Response to aircraft noise is inherently a multivariate function, depending on both direct acoustical quantities and non-acoustical factors. The non-acoustical factors are often thought of as modifiers, but they can often be dominant variables. Noise metrics and supporting social studies have been reviewed for the purpose of potential development of improvements and/or supplements to DNL, and for the ability of their data to accommodate both acoustical and non-acoustical factors.

5.1 Current Status, Metrics, and Potential Metrics

Relevant metrics for level, single events and cumulative impact are:

- Level: A-weighted sound level, with a potential for PNLT if tonal components are present. Sound quality metrics and speech interference metrics have some relevance, but with effect small compared to level and tonality.
- Single events: energy integrated metrics SEL and EPNL are appropriate for sounds with duration in the range associated with aircraft noise
- Cumulative metrics: DNL generally has the best historical scientific support, but has come under question recently as not including all the factors that make up community response, and is not well understood by the public. There are three areas for improvement:
  - Modifying the level, time of day, and number weighting factors used for familiar cumulative metrics. Quantifying those factors requires statistically appropriate data, which has not always been obtained in social surveys.
  - Incorporating, separating out, or accounting for the influence of non-acoustic factors in community response data.
  - Use of supplemental metrics which are understood by the public and but do not yet have a scientific basis. Candidates include NA (Number Above), TA (Time Above) and L_{Amax10}.

  The first follows from the discussion in Sections 1.1 and 4.2 (particularly published conclusions) regarding the inconsistent time of day and number weightings of current metrics. The second follows from the non-acoustic factor discussion in Sections 3.2 and 4.2. The third is implicit in the objective of this study - most supplemental metrics are currently supported only by anecdotal experience.

Fifteen high interest aircraft noise surveys were identified as candidates for further analysis to support improved fametrics. About half were determined to not be suitable because of age, limited scope, or unavailability of data. A few were identified as well worth pursuing for re-analysis, and several others were identified for analysis pending availability of the raw data.

Two observations became apparent during review of the surveys. One was progressive improvements, over time, in design and quality of results. Some older studies matched the rigor of modern ones, but in general the more recent studies have established a high state of the art. The current COSMA study, which has rather ambitious goals, has capitalized on that experience in its survey designs. COSMA planning documents and results to date should be reviewed when planning any new survey.

The second observation is that while some studies were identified as suitable for re-analysis, it is clear that surveys are not lightly undertaken, that they are designed with particular goals, and that the organizations performing them generally perform thorough analysis. There are studies such as the Australian five airport study (AUL-210) that have general and rather flexible data designs, or ones such as the US Air Force Base Study (USA-338) that gather information on non-acoustic factors. But those involve aircraft not typical of today's commercial fleet in the United States, may have been analyzed as much as possible, and/or are not structured such that models like Equations (2) or (3) can be fitted. If results are required that have not already been developed from prior surveys, then it is expected that a new survey that is designed for the candidate metrics would be required.

Supplementing DNL does not necessarily require a new undertaking. Supplemental metrics are permitted by policy, and have been in use for some time. It is routine to provide information beyond DNL to communities, and the DOD guide to supplemental metrics[15] provides extensive information on the use of those metrics, based on real-world experience. If there is, however, a desire to modify or replace DNL, or if a supplemental metric is needed that has science (and not just communication/education) supporting it, then a significant new study is required. Section 5.2 outlines the parameters that must be considered for such a study.

5.2 Requirements for New Survey

Prior to embarking on a new social survey, it is recommended that the surveys identified in the discussion of Table 8 be sought and their data re-analyzed to the extent possible. Some immediately practical information might be obtained, but it is expected that the primary result will be insight for the design of a new survey rather than quantitative results for a model.

A new survey must address the following elements:

- Multiple airports or areas around airports. In order to separate the noise/response variables, it is necessary that there is:
  - A wide range of aggregate noise (DNL).
  - Different combinations of levels and numbers of events for given DNL values.
  - Time of day variations that are not correlated.
  - A variety of aircraft types.
- Quantitative aircraft noise exposure data at each receiver, such that any of the metrics discussed can be computed. For completeness, the time, maximum level and SEL of each aircraft noise event is needed. Flight tracks are also needed, since in some cases residents are annoyed by the occurrence of an overflight rather than the noise. This task is considerably easier with modern airport noise monitoring systems than it was with older studies. For analysis, setting up INM runs that are supported by measurements is ideal.
- The survey questions must address not just annoyance, but also the direct acoustic and non-acoustic factors discussed in this report. Questions must be structured so as to focus on particular responses, (as Fields cautions in his time-of-day analysis[26]), and identifying the contribution of sleep disturbance to annoyance.
- The questionnaire must be designed with the intention of multivariate analysis, such as was done in the 1986 English General Aviation Survey (UKD-324), and not just consider annoyance as the primary output.
- Multi-dimensional, as well as multivariate, analysis should be considered. In order to understand the role of various effects, most variables should be able to be considered as either input or output. For example, it should be possible to determine a dose-response relation of sleep disturbance due to noise, a dose-response relation of annoyance due to disturbed sleep, and a dose-response relation of sleep disturbance due to annoyance. Similar relations for other effects (speech interference, etc.) would then establish the relative contributions of each to annoyance.

These are elements that should be included in future surveys. There is, additionally, a basic element of quantifying noise exposure that needs to be resolved. Indeed, this maybe a significant weak link in developing a representative dose-response relationship. Current methods assume that all survey respondents are exposed to an outdoor noise level, calculated or measured, at a few representative locations. This raises two questions:

- How representative are the outdoor noise estimates for all the survey respondents? This is why detailed noise determination is specified above. There is, however, the question of indoor versus outdoor levels. Kryter[34] attempted to address that with EDNL/EDENL, but his method still left gaps in how this can be handled.
- What is the real noise exposure? In reality, many people are not exposed during the weekday daytime hours (when they are at work), and for much of the time that they are at home, they are indoors. Based on that, daytime noise may be irrelevant, or at least much less significant than evening and nighttime noise. This may be implicitly recognized in the CNEL and L_{den} noise metrics by virtue of there being no daytime weighting.

In addition to quantitative data collection and modeling, subjective studies of public communication should be undertaken. For example, alternate methods of data presentation (such as traditional contour plots of noise versus gradient-shaded maps) can provide significant improvement in developing and maintaining good relations with the public. This kind of study may be out of scope for metric development and rather be classified as public interaction and mitigation, but the context - dealing with and solving adverse impact on communities – is the same.

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References

1. Rosenblith, W.A., and Stevens, K.N., et al., "Handbook of Acoustic Noise Control, Vol. 2, Noise and Man," USAF Report WADC TR-52-204, 1953.
2. Stevens, K.N., Rosenblith, W.A., and Bolt, R.H., "Neighborhood Reaction to Noise: A Survey and Correlation of Case Histories (A)," J. Acoust. Soc. Am., Vol 25, 833, 1953.
3. Stevens, K.N., and Pietrasanta, A.C., "Procedures for Estimating Noise Exposure and Resulting Community Reactions from Air Base Operations," USAF Report WADC TN 57-10, 1957.
4. Beranek, L.L., *Noise Reduction*, McGraw-Hill, New York, 1960.
5. Bishop, D., and Simpson, M.A., "Noise Exposure Forecast Contours for 1967, 1970 and 1975 Operations at Selected Airports", DOT/FAA Office of Noise Abatement, FA68WA-1900, September 1970, BBN Report No. 1863.
6. Environmental Protection Agency (EPA), "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA Report No. 550/9-74-004, 1974.
7. Wyle Laboratories, "Supporting Information for the Adopted Noise Regulations for California Airports," Wyle Report WCR 70-3(R), 1970.
8. Schultz, T.J., "Synthesis of Social Surveys on Noise Annoyance. Journal of the Acoustical Society of America, 64: pp. 377-405, August 1978.
9. Bassarab, R., Sharp, B., and Robinette, B., "An Updated Catalog of Social Surveys of Residents' Reaction to Environmental Noise (1943-2008)," Wyle Report 09-18, November 2009. (Also DOT/FAA/AEE/2009-01 and DOT-VNTSC-FAA-10-02).
10. Federal Interagency Committee on Noise, "Federal Agency Review of Selected Airport Noise Analysis Issues," August 1992.
11. Kryter, K.D, *The Effects of Noise on Man*, Academic Press, New York, 1970.
12. Fields, J.M., and Powell, C.A., "A Community Survey of Helicopter Noise Annoyance Conducted Under Controlled Noise Exposure Conditions," NASA TM 86400, March 1985.
13. Stusnick, E., Bradley, K.A., Molino, J.A., and deMiranda, G., "The Effect of Onset Rate on Aircraft Noise Annoyance. Volume 2: Rented Home Experiment," Wyle Report WR 92-3, March 1992.
14. Fields, J.M., "Data on Noise Environments at Different Times of Day Around Airports," NASA CR 172612, June 1985.
15. "Improving Aviation Noise Planning, Analysis and Public Communications with Supplemental Metrics: Guide to Using Supplemental Metrics," Wyle Report WR 09-27, December 2009, for the Defense Noise Working Group. Available from DNWG as http://www.denix.osd.mil/dnwg/upload/DNWG_Supplemental-Metrics-Report_December-2009.pdf.
16. Plotkin, K.J. et al., "The Effect of Onset Rate on Aircraft Noise Annoyance, Vol 1: Laboratory Experiments," Wyle Research Report WR 91-19, November 1991.
17. Stusnick, E., Plotkin, K.J., Bradley, K.A., Bossi, M.A., Molino, J.A., and Rickert, D.G., "The Effect of Onset Rate on Aircraft Noise Annoyance, Vol 1: Hybrid Own Home Experiment," Wyle Research Report WR 93-22, December 1993.
18. LVNL, Air Traffic Control the Netherlands, Report D/R&D 07/260 version 1.0, "Noise Annoyance Mitigation at Airports by Non-Acoustic Measures".
19. Fields, J., "Effect of personal and situational variables on noise annoyance in residential areas," *J. Acoust. Soc. Am.* Vol 93 (5), May 1993.
20. Wyle Report EPA-NTID 300.3, "Community Noise," December 1971.

21. Le Masurier, P., Bates, J., Taylor, J., Flindell, I., Humpheson, D., Pownall, C., and Woolley, A., "ANASE: Attitudes to Noise from Aviation Sources in England," MVA Consultancy, Final Report, October 2007.
22. Flindell, I.H., Stallen, P.M., "Non-acoustical factors in environmental noise," *Noise Health*, 1:11-6, 1999.
23. Fields, J.M. et al., "Standardized General-Purpose Noise Reaction Questions for Community Noise Surveys: Research and a Recommendation," *Journal of Sound and Vibration*, Vol. 242, No. 4, 2001.
24. ANSI Standard, S12.9, Part 4 – "Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response.
25. Schomer, P.D., Fidell, S., and Mestre, V., "The case for a duration-adjusted loudness metric to assess transportation noise (A)," *J. Acoust. Soc. Am.*, Vol. 128, No. 4, Pt. 2, October 2010.
26. Fields, J.M., "Research on the Effect of Noise at Different Times of Day: Models, Methods and Findings," NASA CR-3888, 1985.
27. Fields, J.M., "The Timing of Noise-Sensitive Activities in Residential Areas," NASA CR 177937, July 1985.
28. Fields, J.M., "The Relative Effect of Noise at Different Times of Day," NASA CR-3965April 1986.
29. Miedema, H.M.E., Vos, Henk, and de Jong, R.G., "Community reaction to aircraft noise: Time-of-day penalty and tradeoff between levels of overflights," *J. Acoust. Soc. Am.* Vol. 107 (6), June 2000.
30. Bassarab, R., "High Interest Survey Methodology and Analysis," Wyle Memorandum to FAA, Dec 20, 2009.
31. Fields, J.M., 'The effect of numbers of noise events on people's reactions to noise: An analysis of existing survey data," *J. Acoust. Soc. Am.*, Vol 75, Feb 1984, pp 447-467.
32. Fields, J.M., "An Analysis of Residents Reactions to Environmental Noise Sources Within an Ambient Noise Context," DOT/FAA/AEE-96/08, 1996.
33. Kryter, K.D., and Pearsons, K.S., "Some effects of spectral content and duration on perceived noise level," *J. Acoust. Soc. Am.*, Vol 35, 1963, pp 866-883.
34. Kryter, K.D., "Acoustical model and theory for predicting the effects of environmental noise on people," *J. Acoust. Soc. Am.*, Vol 125, June 2009, pp 3701-3721.
35. More, S., and Davies, P., "Development of a Model to Predict Annoyance Caused by Aircraft Noise," Proceedings of Internoise 2010, 13-16 June 2010, Lisbon, Portugal.
36. Bauer, M., Collin, D., Iemma, U., Janssens, K., Marki, F., and Muller, U.,"COSMA - Community Oriented Solutions to Minimise Aircraft Noise Annoyance," Internoise 2010, June 2010
37. Schreckenberg, D., and Meis, M., "Effects of aircraft noise on noise annoyance and quality of life around Frankfurt Airport," Final abridged report, Bochum/Oldenburg.http://www.verkehrslaermwirkung.de/FRA070222.pdf
38. Schreckenberg, D., and Schuemer, R., "The Impact of Acoustical, Operational and Non-Auditory Factors on Short-Term Annoyance due to Aircraft Noise," Internoise 2010, June 2010.

Appendix A

Wyle Memorandum to FAA

HIGH INTEREST SURVEY METHODOLOGY & ANALYSIS

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Memorandum

To: Mehmet Marsan, Jim Fields

CC: Clay Reherman, Ben Sharp, Raquel Girvin

Date: 20 December 2009 (*Revised March 2011*)

From: Royce Bassarab

Subject: **High Interest Survey Methodology & Analysis**

1.0 Introduction

In support of the FAA's desire to assist in the identification of further research opportunities related to community noise annoyance, and building upon previous efforts completed by Jim Fields, Wyle was tasked with the identification and preliminary evaluation of "high interest" surveys. This memo outlines the methodology, scope of work, issues addressed, results, and preliminary conclusions.

Four types of high-interest surveys were identified in the scope of work for which Wyle was to identify. Each addresses annoyance within the confines of the criteria used to include surveys in the Catalog. Some research in each of these categories was initiated by Jim Fields in previous work, which formed a basis for the criteria and evaluation of this analysis. This task was designed to identify publications and surveys in the updated 2008 Catalog (including the 521 surveys in the 2001 catalog) that address four categories of surveys:

- Surveys which include a number or level weighting;
- Surveys which analyze a dose/response relationship for aviation and other sources;
- Surveys which include a time of day weighting; and
- Surveys that have evaluated community response during different time periods at the same airport.

Number and level surveys included surveys that attempted to define annoyance in terms of a number of events and potentially events that exceed specific thresholds. Initial criteria was provided by an article by Jim Fields entitled "The Effect of Numbers of Noise Events on People's Reactions to Noise: An Analysis of Existing Survey Data", published in JASA, vol 75, 1984. Surveys that address annoyance from multiple sources, one of which included aircraft noise, are included in the Ambient noise category. These also included surveys which addressed the urban/rural noise environment. Criteria were initially identified in the following document: Fields, J.M.: 1996. An Analysis of Residents' Reactions to Environmental Noise Sources Within an Ambient Noise Context. DOT/FAA/AEE-96/08. Federal Aviation Administration, U.S. Dept. of Transportation, Washington D.C. This analysis only included those surveys that were published or administered near 1995 or more recently. A third category of surveys are those which address the effect of noise during different time periods of day, which include those analysis which offer some form of time of day weighting, and generally include those that occur since 1985. The final category includes surveys which address residents' reaction to noise over time, and potentially provide a comparison of reactions in different years. This includes surveys that have occurred at the same airport following changes in exposure levels if notable development has occurred.

The purpose of this analysis is to evaluate the quality of the high interest surveys and determine if the necessary data or information is available that would provide the means to further study the methods, data, and results. Where information is not readily available through the Catalog effort and files or correspondence maintained by Jim Fields, efforts to contact individual study authors were made. Wyle attempted to identify all relevant studies that are included in the Catalog, regardless of quality, that have addressed one of the high interest topics listed above. The remainder of this memo outlines the methodology, initial results, data collection efforts, and final results. Companion electronic files include an excel database, electronic correspondence between the study author and project team, and data that was received in those efforts.

2.0 Methodology

The analysis methodology was initially suggested by Jim Fields, based on his expertise in the field and previous efforts. The overall methodology can be summarized by the following steps: Previous and current publications included in the Catalog were identified; the methodology, sources, and contents of each survey were evaluated; a high-interest survey database was developed; efforts to contact survey authors was made to collect additional data; and a database of completeness was prepared. These steps are described in further details in the following sections.

2.1 Initial Survey Identification

For the high interest surveys to be useful for further research they must have met recognized standards of quality and completeness of data. Requirements for the quality of the publications and the surveys in which they describe reflect the completeness of the available data and the quality of the survey itself. This includes:

- The required level of detail in the publications or available internal documents
  - Source details: types, operations, etc.
  - Survey methodology
  - Survey length-time
  - Survey instruments and procedures
  - Pre-test of survey instruments
  - Survey site selection
  - Sample design
  - Survey administration
  - Statistical techniques for analysis of results
  - Noise level distributions
  - Integration of attitudinal assessment and physical noise data
- Questionnaire design
  - Types of questions – multiple choice, ranking, open end, etc.
  - Positioning of noise issue in questionnaire
  - Use of descriptors – annoy, disturb, etc.
  - Evolution of questionnaire content
  - Data collection procedure – personal, telephone, mail.
  - Response scales
- Noise data – measured or predicted and metrics used to present results.
- Potential confounding factors, including any apparent biases.

With this criteria and the methodology preliminarily identified by Jim Fields in place, publications were individually evaluated for potential inclusion. Initial survey identification was completed in two phases. First, Wyle evaluated each publication issued in the library of publications from the 2001 Catalog. All of the publications that matched the cutoff dates identified above were evaluated to determine if they met the criteria of a high interest survey. Because each of the publications, rather than 2001 Catalog survey entries, were identified, in some cases multiple publications corresponded to one survey. Likewise, some publications described surveys that met more than one criteria for inclusion.

At the same time, publications that were identified for potential inclusion in the 2008 Catalog were evaluated for inclusion. Overall, publications ranging from 1982 through 2008 were evaluated and a database of completeness was prepared.

2.2 Additional Data Collection

Through coordination with the Project Team, a letter was developed that was designed to request additional materials to provide a more complete analysis of the survey. In some cases, Jim Fields was able to provide author contact information, while other authors' contact information was found by searching the internet or contacting a place of former employment. Jim Fields identified surveys in which no additional efforts to contact authors would be made, due to either a known difficulty in obtaining data from that source, or that the study author was deceased or no longer working within the field. Ultimately, 21 letters were delivered to 16 study authors.

The letters requested a number of items, including actual published papers, conference presentations articles, formal reports, and informal reports, or directions to where these additional materials could be found; a copy of the actual questionnaire (whether a script for telephone interviews or an actual mailed questionnaire); any additional correspondence seen by the respondents; information used to train interviewers in the case of an interviewer-administered survey; information pertaining to the methods used to estimate the noise environment at each dwelling; and the availability of data/results and how difficult that may be to obtain for future analysis (note that we did not request actual data at this time). Additionally, notification regarding the FAA's intent to host a forum to discuss sleep disturbance and annoyance as it relates to the FAA's intended roadmap for research was included.

The following sample letter depicts the methodology for contacting each of the study authors and requesting further information. For each study, Wyle also included a description of the survey as it appeared in the catalog at that time, and the publications on hand to serve as a cross reference. The results of this query provided clarification on the surveys as they appear in the catalog, and provided Wyle with additional details pertaining to the surveys in question.

> July 17th, 2009
>
> Dear Dr. Brooker,
>
> We (Jim Fields and Royce Bassarab) are working with the U.S. Federal Aviation Administration (FAA) to update Jim's Catalog of Social Surveys last published in 2001 (An Updated Catalog of 521 Social Surveys of Residents' Reactions to Environmental Noise 1943-2000, NASA CR-2001-211257, December 2001). Royce and his team at Wyle Research have been developing the updated catalog while Jim has provided files and insight from his previous experiences.
>
> As a part of this project, we are also identifying studies that address high-interest issues for the FAA as explained in the accompanying note from Raquel Girvin of the FAA (FAAProject.PDF). Specifically, your study of areas around the Gatwick-Heathrow helicopter airlink and near Aberdeen airport, referenced in the Catalog as "UKD-225: 1982 British Helicopter Disturbance Study", appears to address the high-interest issue of

the relative importance of noise level and numbers of noise events in determining annoyance. At present we have identified the following publications that describe the methodology or presents study findings:

- Atkins,C.L.R.; Brooker,P.; and Critchley,LB.: 1983. 1982 Helicopter Disturbance Study: Main Report. DR Report 8304. Civil Aviation Authority, London. UKD-225
- Atkins,C.L.R.: 1983. 1982 Helicopter Disturbance Study Tabulations of the Responses to the Social Surveys. DR Communication 8302. Civil Aviation Authority, London. UKD-225
- Atkinson,B.J.: 1983. 1982 Helicopter Disturbance Study: Tabulations of Noise Measurement Results. DR Communication 8303. Civil Aviation Authority, London. UKD-225
- Prescott-Clarke,P.: 1983. 1982 Aircraft Noise Index Study and 1982 Helicopter Disturbance Study: Methodological Report. Social and Community Planning Research, London. UKD-225 UKD-242

We anticipate further communication with you and hope that you can take part in future discussions on this FAA project, as for example, at the Ottawa Forum that is described in the attached note from Raquel Girvin of the FAA (Save_the_Date.PDF). At this time, however, we only need to identify all the publications for this survey and obtain any additional, possibly unpublished, documents that provide more background on the survey.

OUR QUESTIONS:

1. Is the above a complete list of all publications about the survey and its findings (i.e. reports, conference presentations, papers)? (Please publications in any language, not just English)? If not, please list the publications or send us a copy.
2. Can we get a facsimile (exact copy) of the questionnaire (i.e. exactly what the respondent saw or, for interviews, what the interviewer was instructed to read)? (If it is in a publication, and we missed it, just let us know.)
3. Was there any correspondence that was sent or read to the respondent such as a recruitment letter, follow-up reminder, or an introductory script an interviewer used for choosing a respondent? If so, could you send us a copy of the communication?
4. Were there any written training materials or other documented instructions that your interviewers or other personnel were to follow when they talked directly with respondents? If so, could you send us a copy?
5. Do you have any additional informal documents, notes or unpublished reports that you could easily send us which provide more detail about the noise measurement protocol or noise modeling procedures used to establish the local noise environment, that describe the methods used to specify the noise index value that was assigned to each respondent, or that would give us insight into such things as: the nominal location for noise-exposure estimates, the time period covered, the type of sampling or modeling plan that was followed to accumulate estimates, and how general estimates might have been adjusted to give dwelling-specific estimates? (If you have such documents, we would accept them in whatever format is convenient for you.)

6. Have we accurately described your study on the last page of this note? (This information will appear in the updated catalog, so we want to be sure we have it right.)

Please don't go to a lot of trouble answering the above questions, but please do get back to us as soon as possible – within two weeks if at all possible.

Documents and your response can be sent to either of the e-mail addresses below or to the following postal address:

K. Royce Bassarab
Wyle Laboratories
241 18th Street South, Suite 701
Arlington, Virginia 22202. USA

Email: royce.bassarab@wyle.com
fieldses@umich.edu

If you have any questions or comments please use our e-mail addresses (above) or telephone Jim Fields (in the United States) at 240-314-9748 or Royce Bassarab at 703-415-4550 (extension 61). We thank you very much for your attention to this request.

Jim Fields and Royce Bassarab

2.3 Results of Request for Additional Information

Study authors proved very willing to assist in the effort to collect additional information. Correspondence and data received are located in the electronic project database. In some cases, the information provided was in the survey country's native language, while in others, English translations were also provided. Overall, study authors were able to provide many of the needed materials.

3.0 High Interest Survey Results

Table 1 lists each of the High Interest surveys that were identified through the research. In the table, "N" listings correspond to surveys evaluating number of events, "T" listings correspond to surveys involving time-of-day analysis, "M" surveys are those which address ambient impact, and "D" surveys address annoyance changes over time around airports. Overall, approximately 53 high interest surveys were identified (13 number of events, 12 time of day, 11 ambient impact, and 17 annoyance changes over time).

Table 1. High Interest Surveys

ID	CATALOG	TITLE
N1	USA-338	1981 USA Air Force Base Study
N2	SWE-228	1978-80 Swedish Railway Study
N3	SWE-359	Gothenburg 12-Area Traffic Noise Survey
N4	UKD-242	1980 Heathrow Noise Index Trial Survey
N4	UKD-008	1961 Heathrow Aircraft Noise Survey (First Heathrow Survey)
N5	SWE-419	1988-93 Swedish Small Airport Noise Survey
N6	AUL-210	1980 Australian Five Airport Survey
N7	USA-235	1983 Controlled Exposure Helicopter Noise Study
N8	BEL-288	1980s Brussels International Airport Noise Survey
N9	UKD-225	1982 United Kingdom Aircraft Noise Index Study
N10	UKD-324	1986 English General Aviation Survey
N12	JPN-541	2001 Sapporo Hokkaido Railway Noise Survey
N13	UKD-604	2005 Attitudes to Noise from Aviation Sources in England (ANASE)
T1	AUL-210	1980 Australian Five-Airport Survey
T2	USA-219	1980 Salt Lake City In-Home Aircraft Rating Study
T3	UKD-309	1977 Hamble Airfield Survey
T4	UKD-243	1981 United Kingdom General Aviation Airport Survey
T5	FRA-197	1979 French Behavioral Effects of Road Noise Study
T6	FRA-364	1993-94 French 18-Site Time-Of-Day Study
T7	USA-170	1978 U.S. Army Impulse Noise Survey
T8	AUL-589	2005-2006 Australia Nighttime Truck Noise Longitudinal Survey
T9	SWI-534	2003 Zurich-Kloten Aircraft Noise Survey
T10	NET-371	2002 Amsterdam Schiphol Airport Noise and Health Survey
T11	GER-532	2004 German Time of Day Annoyance Survey and Diary
T12	GER-531	2005 Frankfurt Airport New Runway Annoyance Survey
M1	UKD-567	2003 HYENA (Hypertension and Exposure to Noise near Airports) Study
M2	SWI-525	2001 Swiss Zurich-Kloten Aircraft Noise Study
M3	SWE-228	1978-80 Swedish Railway Study
M4	UKD-241	1982 Heathrow Combined Aircraft/Road Traffic Survey
M4	UKD-238	1984 Glasgow Combined Aircraft/Road Traffic Survey
M5	AUL-307	1986 Sydney Aircraft/Road Traffic Survey
M6	AUL-383	1994-95 Sydney Airport Noise Change Survey
M6	AUL-210	1980 Australian Five-Airport Survey
M7	AUL-307	1986 Sydney Aircraft/Road Traffic Survey
M8	CAN-168	1978 Canadian Four-Airport Survey
M9	KOR-554	2004 Korea Airport and Background Noise Survey
M10	KOR-590	2005 Gimpo International Airport Annoyance Survey
M11	SPA-571, UKD-610, NET-575	2002 RANCH Children's Road Traffic and Airport Noise Health Survey (Schiphol, Heathrow, Barajas)
D1	USA-301	1982 Westchester Airport Nighttime Noise Change Study
D2	NOR-311	1989 Oslo Airport Survey
D3	NET-361	1993 Netherlands National Environmental Survey
D4	CAN-168	1978 Canadian Four-Airport Survey
D5	JPN-509	1972-81 Kyushu Airport Opening Survey
D6	GER-363	1988 German Noise Barrier Evaluation Survey
D6	GER-373	1987 Düsseldorf/Ratingen Aircraft/ Road Traffic Survey
D7	USA-203	1978-79 Time-of-Day Study with Annoyance Recording Device
D7	USA-203	1979 Burbank Aircraft Noise Change Study
D7	USA-206	1981 Alabama Three-Site Blast Noise Survey
D8	USA-027	1968 LAX Aircraft Noise Study
D9	USA-082	1973 Los Angeles Airport Night Study
D10	NOR-328	1992-93 Bodö Aircraft Military Exercise Survey
D11	AUL-383	1994-95 Sydney Airport Noise Change Survey
D11	AUL-210	1980 Australian Five-Airport Survey
D11	AUL-383	1994-95 Sydney Airport Noise Change Survey
D12	USA-431	1995 Seattle-Tacoma Airport Noise Survey
D13	CAN-385	1990s Vancouver Airport Noise Change Survey
D14	JPN-551	2005 Japan Narita Airport Noise Effects
D15	NET-533	2002 Netherlands Amsterdam Schiphol Airport Noise and Health Survey
D16	SWI-525	2001 Swiss Zurich-Kloten Aircraft Noise Study
D16	SWI-534	2003 Zurich-Kloten Aircraft Noise Survey
D17	NOR-752	1998-99 Oslo Aircraft Change

Table 2 provides a summary of the information available in each publication or series of publications. The evaluation of information includes all information collected throughout the process, including those which required contacting the survey authors.

Several elements of the surveys were evaluated based on specific criteria. This included:

- Social survey characteristics: This category included an evaluation of whether pretests were conducted, the reasons behind selecting eligible general locations and dwellings, and characteristics about the selection of respondents, how they were chosen, and if any responses were excluded from further analysis.
- Noise Environment: This section includes an evaluation of the estimated noise environment for each respondent, if applicable. Subsections include evaluating whether the survey discussed the time of day or week that a noise measurement represents, the duration that the measurement period represents, the meteorological conditions, and if the nominal location of the noise monitoring equipment (a certain distance from the façade, center of room, etc).
- Noise Modeling: If noise modeling was conducted, the evaluation quantified the completeness of the model name, type, and specifications, or the algorithms used for noise source emissions, the source data for the noise model, the algorithms used for noise propagation, and the source of data.
- Noise Measurements: If noise measurements were conducted, the database includes an evaluation of the instrumentation, the noise measurement protocol, and the method of sampling.
- Judgment of Completeness: For each of the categories of surveys, an overall estimate of the completeness of data available for each survey was conducted. This judgment included:
    - The overall precision of the exposure for each respondent for the nominal condition and location.
    - Number/level surveys: The precision of the estimates for the purpose of estimating the number/level trade off. Special consideration was given to how numbers of events are counted and how the levels of those events are combined.
    - Time-of-day surveys: The precision of the estimates for the purpose of estimating the time-of-day weighting. Special consideration was directed at the methods for estimating the exposure in each time period and how the methods might affect the estimate of the time-of-day weighting.
    - Ambient impact surveys: The precision of the estimates for estimating the effects of ambient noise. Special attention was directed to the nominal position for noise from surface-based transportation.
    - Airport annoyance change surveys: The precision of the estimate of changes in aircraft noise exposure. The consistency in the noise estimation procedures and the social survey methods between the different years.
- Published Conclusion: If study conclusions were made, the survey database indicates how thorough the conclusion is.

In Table 2, the nomenclature described corresponds with the following codes:

1. Full information is available in document
2. Some information available in document; full information is probably available
3. No information available in document; full information is probably available
4. Unable to determine what information is available
5. Not addressed

Table 2. High Interest Survey Analysis

SURVEY ELEMENTS	SURVEY REFERENCE																						
	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N12	N13	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
2. SOCIAL SURVEY																								
Questionnaire	2	3	3	1	2	1	1	2	1	1	2	1	1	1	1	1	2	2	1	2	2	2	2	2
Pretests Conducted	4	4	3	1	4	3	1	3	1	3	3	1	1	1	3	3	1	3	2	3	3	3	3	2
Study Area Selection Criteria	2	2	2	1	2	2	1	2	1	1	2	1	1	1	1	2	2	2	1	1	1	1	2	2
Dwelling Selection Criteria	2	2	2	1	3	2	1	3	1	1	2	1	1	1	1	2	2	3	1	1	2	3	3	2
Inhabitant Restrictions	4	1	1	1	2	2	1	3	1	1	1	1	1	1	3	2	3	3	1	2	1	3	3	2
Respondent Selection within Dwelling	4	3	1	1	4	2	1	3	1	1	1	1	1	1	1	2	3	3	1	3	2	3	3	2
Respondent Exclusions	3	1	1	1	3	2	1	3	1	1	2	1	1	1	3	2	3	3	1	3	1	3	3	2
3. NOISE ENVIRONMENT																								
Noise - Time	3	1	1	1	3	1	1	1	1	1	3	2	2	1	-	2	1	2	3	3	1	1	1	2
Noise - Period	1	4	1	1	3	1	1	1	1	1	1	2	1	1	-	1	1	2	1	3	1	1	1	1
Met. Conditions	4	4	3	3	3	5	3	5	3	3	3	3	4	4	4	4	3	3	3	3	3	-	5	-
Respondent Location	4	4	3	1	3	4	2	5	1	2	2	2	4	1	-	2	2	3	3	3	3	1	3	1
4. NOISE MODELING																								
Noise Model	-	-	-	-	-	3	-	-	-	-	3	1	3	-	1	-	-	1	2	3	1	1	1	1
Input Data Source	-	-	-	-	-	3	-	-	-	-	3	1	2	-	1	-	-	3	1	3	1	3	2	2
5. NOISE MEASUREMENTS																								
Instrumentation	2	4	2	3	3	3	3	1	1	3	3	2	3	2	3	1	3	3	1	3	-	-	-	-
Measurement Protocol	4	4	2	1	3	2	3	3	1	2	2	2	2	2	3	2	3	3	2	3	-	-	-	-
Method of Sampling	4	4	2	1	3	2	2	3	1	2	2	2	2	1	3	2	3	3	2	3	-	-	-	-
6. JUDGEMENT OF COMPLETENESS																								
Noise Exposure	2	2	2	1	2	1	2	2	1	1	2	1	2	1	2	1	2	2	2	3	1	2	2	2
Number/Level	2	2	1	1	2	1	1	2	2	2	2	1	5	5	4	2	5	5	2	5	5	5	5	5
Time-of-Day	2	5	5	1	5	5	5	2	2	5	3	5	1	1	2	2	1	2	1	1	1	1	2	2
Ambient Impact	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	2	5	5	5	1	1	2	5	5
7. PUBLISHED CONCLUSION																								
Number/Level Weighting	2	1	1	1	1	1	1	2	3	3	2	1	5	5	4	2	5	5	2	5	5	5	5	5
Time of Day	4	5	5	1	5	5	5	2	3	5	3	5	1	1	2	2	2	2	1	5	1	1	2	2
Ambient Impact	5	5	5	5	5	5	5	5	5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	2	5	5	5	1	2	2	5	5

Table 2. High Interest Survey Analysis

SURVEY ELEMENTS	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	D1	D2	D3	D4	D5	D6	D7	D8	D9	D11	D12	D13	D14	D15	D16
2. SOCIAL SURVEY																										
Questionnaire	2	2	2	2	2	1	1	1	2	3	2	1	1	3	2	2	2	1	1	1	1	1	1	2	2	2
Pretests Conducted	3	3	3	2	1	3	1	1	3	3	3	1	2	3	3	3	3	2	3	3	1	3	2	3	3	3
Study Area Selection Criteria	1	1	3	2	2	2	1	1	1	3	2	1	1	3	2	2	2	1	2	1	2	1	1	1	1	1
Dwelling Selection Criteria	1	1	3	2	2	2	1	1	1	3	2	1	2	3	3	3	2	1	3	2	2	1	1	1	3	2
Inhabitant Restrictions	1	1	3	2	2	2	1	1	3	3	2	1	1	3	3	3	3	1	2	1	3	1	1	3	3	1
Respondent Selection within Dwelling	2	3	3	2	2	2	1	1	1	3	2	1	1	3	3	3	3	2	3	2	1	1	1	1	3	2
Respondent Exclusions	1	1	3	2	2	2	1	1	3	3	2	1	1	3	3	3	3	1	3	2	3	2	2	1	3	1
3. NOISE ENVIRONMENT																										
Noise - Time	2	2	3	1	3	3	1	1	1	2	2	1	1	3	2	3	2	1	3	3	1	2	1	1	1	1
Noise - Period	2	2	3	1	3	3	1	1	1	2	2	1	1	3	1	3	2	1	3	3	1	1	1	1	1	1
Met. Conditions	-	4	3	3	3	3	3	3	3	3	5	2	3	3	3	3	3	3	3	3	3	3	-	3	-	3
Respondent Location	-	2	3	3	3	3	2	3	1	3	2	2	1	3	3	3	3	1	3	3	3	3	2	2	1	3
4. NOISE MODELING																										
Noise Model	1	1	3	-	3	1	-	1	-	2	1	-	1	3	-	-	-	-	3	3	2	-	1	-	1	1
Input Data Source	1	3	3	-	3	2	-	1	-	3	1	-	1	3	-	-	-	-	3	3	2	-	1	-	3	1
5. NOISE MEASUREMENTS																										
Instrumentation	-	-	3	3	3	3	1	3	1	-	-	1	3	3	3	3	3	1	3	3	3	1	-	2	-	-
Measurement Protocol	-	-	3	3	3	3	1	3	2	-	-	1	3	3	3	3	3	1	3	3	2	1	-	2	-	-
Method of Sampling	-	-	3	3	3	3	1	3	1	-	-	1	3	3	3	3	3	1	3	3	3	1	-	2	-	-
6. JUDGEMENT OF COMPLETENESS																										
Noise Exposure	2	2	3	2	3	2	1	1	1	3	2	1	1	3	2	3	2	1	2	3	2	1	1	2	2	1
Number/Level	5	5	2	5	5	5	5	5	5	5	5	1	2	3	5	5	4	5	5	5	5	5	5	5	5	5
Time-of-Day	2	2	5	5	5	5	5	5	5	5	5	1	5	3	5	5	5	5	5	5	5	5	5	5	5	1
Ambient Impact	2	2	2	2	2	2	1	1	1	1	2	5	1	3	2	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	5	5	5	5	5	5	5	5	1	1	3	2	2	2	1	2	1	1	1	1	1	2	1
7. PUBLISHED CONCLUSION																										
Number/Level Weighting	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Time of Day	2	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1
Ambient Impact	2	1	2	2	2	2	1	1	1	2	2	5	1	5	2	5	5	5	5	5	5	5	5	5	5	5
Airport Annoyance Changes	5	5	5	5	5	5	5	5	5	5	5	1	1	2	2	2	2	1	2	1	1	1	1	1	2	2

3.1 High Interest Survey Summary

Overall, a number of surveys were found that may provide additional insight and analysis for each of the high interest topics presented in this memo. Future work could entail a detailed evaluation of each of the sources of material, present either in the publications or retrieved through coordination with the study authors. All information is present in the companion electronic files accompanying this memo. It should be noted that, in some cases, authors indicated that information was available, but did not provide the actual documents, which followed our request.

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