Planning for Airport Noise

The Roar of Discontent

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Abstract

Aircraft noise is one of the most noticeable environmental impacts of an airport for surrounding communities. The impact of noise on human health, property value, and lifestyle makes it a cornerstone for environmental regulation, development policy, and community relations. The economic ramifications of noise-driven policies can be enormous. A framework for noise quantification, reporting, and visualization has arisen to cope with these issues. This report aims to describe the physical characteristics of aircraft noise, metrics used to express and rank noise impacts, and environmental reporting requirements. The importance of noise is illustrated in two real-world case studies. The first is an airside expansion project at Boston's Logan Airport that culminated in the opening of the new Runway 14/32. The second is Greener Skies over Seattle, a current airspace procedural program that illustrates the central role of noise in NextGen projects.

Introduction

Aircraft noise is perhaps the most readily-apparent environmental detractor that arises from modern large-scale air transportation. Quality of life for people living in surrounding communities can be significantly impacted by the noise from arriving and departing aircraft. A large body of research focuses on the negative health and cognitive impacts of repeated noise exposure. Apart from long-term health impacts, the interruption of communication due to jet noise is a harmful influence in schools, places of worship, and homes. Naturally, communities and homes that are strongly impacted by aircraft noise have reduced property valuation. Therefore, there is strong incentive for communities to actively oppose aviation activities, especially airport expansion that impacts their neighborhoods. This presents problems for the FAA and airport managers who must ensure that airport capacity satisfies increasing demand throughout the National Airspace System.

While the phenomenon of aircraft noise is not new, the adoption of jet-powered airliners in the 1960s resulted in a new focus on the subject. Early jet aircraft were extremely loud and required larger runways than the propeller-driven equipment they replaced. Airports expanded and became noisier at a rapid pace, impacting neighborhoods that had never dealt with the problem. With the advent of the National Environmental Policy Act of 1969, a national framework for discussing and regulating environmental issues became available. That year, aircraft noise certification standards were also introduced to provide acceptable noise limitations. Since that time, certification standards and noise mitigation procedures have become central to most aviation developments, from aircraft design through airline scheduling and airport operations. The economic ramifications of these policies is significant.
Noise is caused by a combination of aircraft aerodynamics (such as the turbulent flows around landing gear and high-lift devices), propulsive mixing in the exhaust plume, and mechanical vibration within the engine and aircraft systems. The noise signature is particularly distinctive relative to other background sounds due to the high-pitched pure tones generated by turbine engines [1]. Technological advances continue to reduce aircraft noise. Regulators and airport authorities attempt to address the significant impact of aircraft noise through a variety of techniques beyond this gradual technology evolution. Noise abatement operational procedures, flight path design, and curfew periods help reduce noise impact. Land use regulations and strategic zoning also prevent residential and school construction in highly-impacted areas.

This report introduces the metrics most commonly used in noise analysis and the noise-related environmental regulations currently used by the Federal Aviation Administration. The focus of the report is on the airport noise problem in the context of the US National Airspace System. While many other nations follow similar procedures, the specific reporting requirements and techniques described here are specific to the Federal Aviation Administration and the Council on Environmental Quality. The field of noise analysis is complicated by interwoven regulations, exceptions, and exclusions that cannot be addressed in this report. The intent is to provide a flavor for the environment of noise reporting in the modern airport environment. To that end, two case studies are presented to demonstrate the handling of projects with both high and low noise impacts. These projects are the construction of Runway 14/32 at Boston Logan Airport and the recent development of new RNP approaches in Seattle, respectively. The relevant regulatory hurdles and community response are compared and contrasted for the two projects.

**Aircraft Noise Metrics**

While the concept of ‘noise’ is superficially simple, the physical and psychological complexities of the subject lead to difficulties in description and quantification. Fundamentally, noise is sound that is unwanted due to its loudness, pitch, or other characteristics. Sound itself is pressure variation relative to steady-state pressure within a medium, normally measured in decibels (dB). Sound pressure level (SPL) is defined simply based on this concept:

\[ SPL = 20 \log\left(\frac{p_{rms}}{P_{ref}}\right) \text{ dB} \]

Where \( p_{rms} \) is the root-mean-square of pressure variation about the reference pressure \( P_{ref} \). One method for determining “noise”, or unwanted sound, is to compare raw SPL values for normal life soundscapes and noise-generating events. However, human perception of SPL varies greatly as a function of sound frequency or tone. A given SPL generated at 3,000 Hz is perceived as ‘louder’ than the same SPL generated at 50 Hz. [2]

As a result of this frequency effect on perceived loudness, quantifying noise is complicated beyond the simple definition of SPL. In addition to frequency, several qualities of a sound (sharpness, tonality, roughness, and fluctuation strength) impact perceived noisiness [1]. Most of these effects vary
between individuals in absolute terms (total SPL tolerance) as well as relative importance (i.e. frequency vs. sharpness). Therefore, creating a quantitative metric for noise is inherently challenging.

The standardized reporting methods used in most transportation studies address some of the subtleties of noise compared to pure quantitative sound pressure. The methods most commonly used in industry are based on research performed during the 1970s and before, gradually becoming accepted as common practice and adopted as the “common-language” of noise analysts and regulators. Several noise metrics are commonly reported to address various aspects of the noise perception problem. The continued use of these metrics is useful from the perspective of industry standardization, although future metrics that incorporate modern noise research could allow more relevant noise analyses. The following discussion presents a partial list of metrics currently in use with a discussion of intended usage and practical limitations.

**Single Event Metrics**

While the aggregate impact of noise on communities depends on the entire daily distribution of flights tracks and operational strategies, each individual flight has an instantaneous impact on community annoyance. Therefore, a class of “single-event” noise metrics has been established to allow for quantification of each noise event. The purpose of these metrics is to ensure that no single event is noisier than acceptable community standards, regardless of frequency or time of day.

**Maximum Sound Pressure Level**

The simplest metric for single-event noise reporting is the maximum SPL occurring from that event. This metric measured full-spectrum SPL as a single location relative to the base event. It gives a scientifically-valid measure for maximum sound intensity due to an event, but does not address any of the other acoustic characteristics that define human noise perception.

**A-Weighted Sound Exposure Level**

As discussed in the introduction to aircraft noise metrics, human response to a given SPL depends upon the frequency of that sound. A given sounds intensity results in a different perception of noise depending on the frequency of that noise. Scientific exploration of these spectral effects began in the 1930s [3], with refinements and applications continuing for the next several decades. One strategy to account for spectral noise sensitivity is to apply a masking function that weights high-sensitivity frequencies most heavily. The filter function used most frequently is referred to as A-weighting, which amplifies the intensity from frequencies near the middle of the audible spectrum. The A-weighted filter function is shown in Figure 1.
A-weighted sound pressure level (commonly shortened to dBA) has become the de-facto standard for many noise certification purposes, including applications in transportation and consumer electronics [4]. While the filter has the generally desirable impact of emphasizing the frequencies to which humans are most sensitive, it does so in an approximate manner that attenuates the impact of lower frequencies too aggressively while missing the spectral subtleties of hearing response. Additionally, the A-weighted filtration has been shown to be a valid predictor of perceived noise in steady-state sound conditions only, while aircraft noise is highly dynamic as a function of atmospheric damping and sound directivity.

**Effective Perceived Noise Level**

There have been many attempts to improve the deficiencies of A-weighted filtration for perceived noise calculation. One of these is the Effective Perceived Noise Level (EPNL), which uses more refined spectral noise response data to scale total noise due to a mixed-frequency event [5]. Equal perceived loudness contours, such as the one shown in Figure 2, illustrate the increased fidelity of the model over the simple A-weighting shown in Figure 1. The intended effect, similar to A-weighting, is to capture human sound intensity perception rather than raw noise intensity. EPNL corrects for several factors, including extended exposure and the presence of particularly obnoxious tones.
Measuring Single Event Metrics

Single event metrics can be determined using specialized microphones spectrally tuned for the desired metric. They can also be calculated by applying weighting filters in post-processing using data from full-spectrum microphones. Direct measurement is generally applied for maximum or A-weighted SPL, while EPNL is generally calculated based on raw measurements. Either method requires careful measurement to isolate event noise, given directivity and atmospheric damping effects. Spectral analysis, whether performed analytically in post-processing or mechanically in the microphone itself, must carefully match the intended attenuation profile.

Cumulative Metrics

While single-event metrics are meant to describe the instantaneous impact of a single flight in a single location, cumulative metrics aim to assign a single value for overall noise impact at an airport averaged across all operations. Such an averaging allows consideration for fleet mix at an airport and flight time of day distributions. Fundamentally, cumulative metrics recognize that repetitive noise exposure at a low level can be as much of a nuisance a community as a single high-noise event.

DNL

The day-night average noise level (DNL) is the most commonly-used cumulative metric. DNL is calculated as an average continuous daily A-weighted noise level expected because of aviation activity. Night time activity between 10:00pm and 7:00am is penalized with an additional 10dBA to reflect the lower background noise experienced during those hours as well as the sleep disruption caused by singular loud events. This metric has been the regulatory benchmark in the United States and Europe since airport noise became part of required environmental assessment [1].
There are several drawbacks to using DNL as the primary noise evaluation metric for airports. First, because the metric is an average over a full 24-hour day, single high-noise events cannot be detected. Maximum sound level is usually significantly higher than DNL, thus obscuring the true noise impact of an overflying aircraft. Additionally, the night-time penalty of 10 dB is not fully justified by scientific research on lifestyle and health impacts. The time window for which this penalty is effective is also debatable, leading to potential tension between airline schedulers, airport planners, and community members.

65dB is the standard DNL threshold used to determine land use requirements, mitigation funding eligibility, environmental impact compliance, and other important airport economic impacts. Thus, the 65dB geographic DNL footprint has become one of the most important noise metrics reported by airports. Apart from the legal requirements motivating this focus on 65dB footprints, quality-of-life advocates focus on 60dB, 55dB, and even 50dB DNL contours. In order to minimize noise complaints, many airports invest in noise programs outside the legally-binding footprint [6]. As aircraft technology permits quieter operation [7], movement to a lower DNL threshold for legal mitigation will become more likely [7].

**CNEL**

Community Noise Equivalent Level is similar to DNL in that night operations between 10:00pm and 7:00am are penalized by 10dB. However, evening flights between 7:00pm and 10:00 also penalized by 5dB. This is intended to recognize the impact of aircraft noise during a period when many people are relaxing, socializing, and preparing for sleep. The State of California is the only jurisdiction that uses CNEL in lieu of DNL, which results in larger noise contour calculations. The drawbacks and benefits of CNEL are similar to those for DNL.

**Other metrics**

Airport noise offices, development planner, regulators, and communities frequently propose and use alternative noise metrics to those presented here [8]. For example, cumulative metrics specific to the standard school day help airports plan traffic flows around highly-impacted schools where jet noise can significantly impact the teaching environment. Audibility metrics are used to evaluate jet noise impacts in national parks, where background noise is low and noise exposure is unwelcome. The time spent above certain sound intensity levels can also be used to evaluate the impacts of aviation on speech, a factor that heavily influences noise complaint rates.

**Perceived annoyance**

The ultimate objective of any noise study is to quantify the psychological impact of noise on people in surrounding communities. If a given combination of sound characteristics does not produce annoyance, there should be no concern with that sound source. However, the meaning of ‘annoyance’ and the resulting analysis techniques are widely debated amongst experts and impacted communities [9]. In general, annoyance is a function of sound intensity, tonality, exposure frequency, time of day, and personal preference among many other factors. The general approach to quantifying annoyance is to correlate the measurable noise metrics introduced above with levels of subjective annoyance reported by sample subjects. These survey methods result in statistical distributions which are
converted to annoyance functions using simple regression methods. Using these annoyance functions, appropriate regulatory thresholds for noise metrics can be established. For example, early synthesis done by Schultz [10] led to the establishment of 65 dB DNL as a key regulatory cutoff for community noise mitigation programs, as shown in Figure 3.

![Figure 3. Schultz Curve relating A-weighted DNL to community annoyance](image)

While this method is logical in theory, its practical application is complicated by the large variation in community expectations between people and over time. Significant research effort has been devoted to quantifying annoyance levels. These studies attempt to refine methodology for collecting annoyance attitude data as well as the mathematical regression models used to fit these results. While refined models are available as a result of this work, most have not been implemented by regulators or analysts. [1] Correlating measurable sound characteristics with community annoyance is central to the fundamental premise of noise regulation – to mitigate impacts of aircraft noise on quality of life for surrounding communities. Therefore, this correlation remains one of the great research and implementation challenges for aviation environmental specialists.

### Planning and Reporting Requirements

The National Environmental Policy Act (NEPA) of 1969 established new environmental assessment requirements for Federal agencies undertaking development work. The act provides recourse for citizens and other concerned parties to provide input during this process, opening a community forum about large-scale projects impacting shared resources. As the national airport and airspace network requires frequent and large-scale development projects involving environmental impact or mitigation, the FAA provides specific guidance beyond NEPA in the form of the Airport Environment Program (AEP). This program addresses environmental impacts in many categories including air quality, wildlife impact, land use, and sustainability. Guidance and requirements on airport noise are also provided under the AEP. This section describes some of the legal reporting requirements related to airport noise as well as special categorical exclusions for certain types of improvements.
**FAA Airport Environment Program**

**Part 150: Noise Compatibility Planning**

In 1979, Congress enacted the Aviation Safety and Noise Abatement Act with a series of new requirements for the interface between community and airport. The FAA complied with the new law in 1981 with an addition to the Code of Federal Regulations, 14CFR Part 150. The law prescribes the methods by which airports should prepare noise exposure maps (NEMs) and calculate population noise exposure. It also establishes the Integrated Noise Model (INM) software as the standard tool for generating DNL noise exposure contours. Most importantly, the law provides a framework for establishing Noise Compatibility Programs (NCPs). These include appropriate land use and zoning in high-noise areas, as well as mitigations such as sound insulation for qualifying homes [11].

Participating in the Part 150 program is voluntary, but the benefits of doing so are potentially quite large [12]. Once a Part 150 noise study is accepted, the airport authority may recommend two types of programs. The first are operational mitigations, including flight path adjustments and runway use guidelines. Once an NCP is accepted, the FAA has 180 days to implement the operational guidelines. The second type of program involves land use, so areas within high-noise DNL contours can be targeted with restrictive zoning (such as industrial or agricultural use). Existing residences may qualify for federally-funded noise insulation as well. Both of these land-use mitigations benefit airports by reducing noise complaints in the short term. In the long term, appropriate zoning prevent development in noise-sensitive areas which inevitably lead to higher complaint rates and operational restrictions.

A Part 150 noise compatibility study, as a subsidiary of the NEPA, is intended to be an open and collaborative process between airports, communities, and the FAA. For this reason, the process can be lengthy and contentious. Airports choose to participate in the Part 150 when the benefits discussed above outweigh the significant effort and cost for preparation. In general, the noise mitigation programs funded by the FAA as a result of a Part 150 program reflect very positively on airport management within the community (for example, by insulating highly-impacted homes) without burdening the airport with related costs.

**Part 161: Noise-Related Access Restrictions**

There are several methods for reducing the size of the 65dB DNL footprint at an airport. One is to reduce the number of penalized night-time operations between 10:00pm and 7:00am. The other is to change runway configurations, utilization, and approach paths to accommodate existing traffic at more acceptable noise levels. The final method is to limit airport access for particularly loud aircraft. Noise certification standards under Part 36 of the Federal Aviation Regulations categorize different aircraft types into four “stages” [13]. Using these standards as a guideline, airports can limit access by certain categories of aircraft. However, this tiered access can cause equitability concerns from the airline perspective. Therefore, Part 161 is in place to ensure that noise-related access constraints are put in place using well-defined policy. The intent is that such programs are used as a final resort rather than a primary noise-mitigation technique.

**FAA Environmental Impact Policies**
Environmental Assessments and Impact Statements

For many projects, the FAA has ultimate authority and responsibility to approve development programs executed by non-federal contractors. To ensure appropriate care in this exercising this authority, environmental impact policies and procedures have been put in place under FAA Order 1050.1E [14]. The guidelines help ensure that FAA actions comply with guidance from the Council on Environmental Quality (CEQ) in the Executive Branch are complied with in the aviation sector. These policies address noise amongst many other environmental components of airport infrastructure development. For major construction projects, such as new runways and taxiways at an airport, a full environmental impact statement (EIS) is required. This is an expensive and lengthy process that requires public input, original research, and mitigation strategies.

The EIS can slow development projects considerably. In cases with minimal expected environmental impact, an exhaustive EIS is not required. Instead, an Environmental Assessment (EA) is prepared that compares the environmental effects of a proposed change compared to alternative courses of action, including the no-action option. In practice, the EA is used for projects such as new approach procedures that do not require direct modification of the land surrounding an airport but do have impacts on noise and air quality. The intent is for these reports to be concise and quickly-approved, although political challenges encountered during procedural implementation motivates many airport authorities and consultants to err toward more exhaustive analysis in both EA and EIS documents [15].

Categorical Exclusions

Some procedures are implemented very routinely, or with sufficient urgency, such that the full EA process cannot be followed without severely hampering development. In these cases, exceptions to the requirements in Order 1050.1E are written into the guidelines and occasionally expanded upon by Congress. For example, one of the cornerstones of the NextGen national airspace system modernization program is the implementation of performance-based navigation (PBN) for airline navigation. Under PBN, aircraft fly much more precise and predictable paths. With this capability, flight paths can be tuned to reduce noise during approaches and departures from airports. Under normal conditions, each new PBN program would require a full EA. The FAA Modernization and Reform Act of 2012 established a categorical exclusion for these types of procedures [16]. While the Categorical Exclusion often leads to confusion amongst the airport community and requires extensive clarification, it has the capacity to reduce processing times for an important class of procedures [17].

Case Study 1: Runway 14/32 at Boston Logan Airport

The construction of a new runway is a major undertaking for any airport. In terms of engineering and construction logistics alone, such a project requires intricate planning. Environmental, operational, and community considerations compound the process into one of the most demanding airport expansions possible. Runway 14/32 at Boston Logan International Airport is a prime example of the politically charged world of airport expansion, with a gestation period of some 34 years between 1974 and the final opening in 2006 [18]. Debate over community noise impact played a key role in the development of this new runway.
**Background**

Boston Logan Airport, located just one mile east of Boston’s commercial core, has long struggled with the growing demand relative to its constrained geographic footprint shown in Figure 4. Originally developed before the advent of jet aircraft and high-frequency airline service, the airport has consistently struggled to maximize capacity given changing technologies and demand. The modern era of this expansion began in the 1960s, when the airport authority (Massport) reclaimed portions of local neighborhoods through negotiated and eminent-domain land acquisitions.

![Figure 4. Satellite view showing proximity of Logan Airport to downtown Boston and multiple geographic barriers](image)

The land-area expansion of the 1960s and 1970s was deemed necessary by airport and government officials for the purpose of runway expansion. Extended runways were needed to accommodate the influx of new wide-body jet airliners then entering production. The airport is constrained geographically by Boston Harbor, which surrounds it, as well as densely-populated residential and commercial centers. Therefore, the airport’s expansion plan encroached on both the waterways (through land reclamation) and the surrounding communities. Unfortunately, the abrupt method by which the land acquisition occurred caused strong anti-airport sentiment to arise in neighboring communities, particularly in the neighborhood of East Boston directly abutting the airport. Community activist groups formed in response to the aggressive expansion at Logan [18]. Figures Figure 5, Figure 6, and Figure 7 show some of the symbolic images from the East Boston neighborhood anti-airport campaign waged throughout the 1970s and 1980s. The period was characterized by extremely divisive politics on the subject of airport expansion. Throughout this period, a new northwest/southeast runway located to the southeast of the existing runway complex was a common proposal and topic for debate. The status of this proposal, eventually to become Runway 14/32, alternated with the leadership of the airport, city, and state. Throughout the changing political climate during these decades, community opposition remained largely unified and tended to define the debate.
Figure 5. Community activist Mary Stack poses with ear guards and a newspaper clipping of a recent meeting with Boston Mayor Ed White, 1973 (Image: Michael Philip Manheim [19])

Figure 6. Residents of East Boston discuss notice of landlord meeting with Massport to discuss sale of homes, 1973 (Image: Michael Philip Manheim [19])
Between 1991 and 2006, Boston Logan International Airport ranked as one of the most congested airports in the United States [20]. Figure 8 shows the schedule distribution and nominal VFR capacity at Logan in 1993. The airport was scheduled to operate near capacity for much of each day, with a period every afternoon with scheduled movements exceeding airside capacity. Congestion and delays at Logan were some of the highest in the nation that year, with particular runway configurations and weather conditions causing extreme disruptive delays on a regular basis. A new administration in the city of Boston and the board of Massport also supported a rekindled effort to build Runway 14/32.

The stated purpose of the runway was to increase airport capacity during conditions of northwesterly wind. In conditions of northeasterly and southwesterly winds, the existing runway configuration allowed simultaneous visual operations on three runways. These wind conditions prevailed 46% of the time. However, northwesterly winds prevailed 37% of days and reduced the number of simultaneous visual runways to two. These conditions, summarized in Figure 9, constrained...
the capacity of the airport, increasing delays and congestion [21]. The runway was proposed as a reliever unidirectional runway to accept overflow arrival demand during conditions of northwest wind.

Runway 14/32 was proposed as part of a larger “airside improvement program” that included a new centerline taxiway between the 4/22 runways, improved runway safety features, and navigational upgrades on several runways allowing approaches in reduced visibility conditions. The full airside improvement program suite of proposals is summarized in Figure 10. It is important to note that the environmental analysis performed for the Runway 14/32 project simultaneously addressed many of these other projects, although the noise analysis focused predominantly on the new runway proposal due to the alteration in approach and departure paths it entailed.
Players

The Runway 14/32 process became political to such an extent that an enormous variety of stakeholders became involved. The stakeholders all had specific responsibilities and concerns. The environmental review process was noteworthy for bringing all of the stakeholders together in a process of negotiation, debate, and compromise.

Politicians

The primary political players in the environmental review process (occurring between 1998 and 2003) were the immediate representatives of the communities impacted by flight paths to and from Logan. For example, the mayors of 30 nearby communities designated representatives to provide input on noise policy planning as well as writing direct letters of opposition to the FAA and other parties. The strongest and most consistent voice opposing the new runway was US Congressman Michael Capuano, representing the Massachusetts 7th District. Mayor Thomas Menino of Boston was also an influential voice in opposition to the project. Senator John Kerry from Massachusetts wrote letters on behalf of impacted communities. In all, 56 different letters from political leaders were received during the comment period for the EIS on the airside improvement plan for Boston Logan Airport [22]. Unofficial lobbying and communication was much more extensive, although often undocumented.

Communities

Communities provided input during the environmental review process with various levels of organization. Some communities formed specific taskforces to address noise and air quality concerns, while others relied on direct action by concerned citizens in a public forum. The FAA hosted several transcribed public forums to receive comments on the proposed environmental impact statement. These comments were required to be addressed as part of the EIS process, meaning that officially-registered comments by citizens were a central part of EIS revisions.

FAA

The FAA was primarily responsible for the moderation, evaluation, and approval of the EIS. In collaboration with the EPA, the FAA provided the final approval (“Record of Decision”) and associated stipulations for all noise impacts and mitigations on the new runway construction. Officials from the FAA Northeastern offices were directly involved with the detailed production of the EIS, while the national office (including the Administrator in a supervisory role) was involved with major revisions and approvals.

Massport

Massport provided the original motivation for the project. As the primary beneficiary of a successful EIS and new runway, Massport was centrally involved with the justification and drafting of all proposed projects and procedures. Officials from the airport authority were among those who interacted directly with members of the community, including responsibilities associated with individual noise monitoring and addressing individual noise grievances.
**EPA**

The Environmental Protection Agency reviewed the EIS along with the FAA’s proposed Record of Decision at various phases in the environmental review process. The fundamental role of the EPA was to ensure compliance with the National Environmental Protection Act [23].

**Consultants**

The actual detailed analysis for the EIS was performed by multiple consulting firms. These firms were employed independently by Massport and surrounding communities to ensure equitable noise analysis. The role of the Massport consultants was to generate the EIS documents in accordance with Massport proposals and intentions. The role of external consultants was to verify the quantitative outputs of the EIS.

**Noise-Specific Environmental Process**

As introduced earlier, an Environmental Impact Statement is the most comprehensive environmental review required for airport-related projects. It is required for projects with significant environmental impacts with potential requirements for mitigation, as outlined in FAA Order 1050.1E. The noise analysis required forecasting fleet mix and traffic levels for high-traffic and low-traffic estimates, along with anticipated flight tracks accounting for procedural deconfliction given proposed runway configurations. A schematic showing the forecast arrival and departure corridors for Runway 14/32 is shown in Figure 11.

![Figure 11. Existing jet flight tracks (green), existing turboprop flight tracks (blue), proposed Runway 14/32 flight tracks (red).](Figure: Airside Improvements Plan EIS [24])
Given a set of assumed runway usage, fleet mix, and traffic levels, no-action and proposed-action DNL contour footprints were generated using standard INM methodology as prescribed in FAA Part 150. The output contours for a high-traffic forecast scenario is shown in Figure 12. The footprints were combined with detailed census data to provide estimated noise exposure impacts due to operations on the new runway compared to the no-action alternative. The population exposure metrics were extended to address concerns of social equity. A major community concern was that the new runway would disproportionately impact minority and low-income segments of the population. INM and census analyses were used to demonstrate that such an effect was neither intended nor in fact likely.

The EIS drafting process began in 1995, with an initial draft released to significant stakeholders directly in 1999. The draft EIS was also available to community members for review at several community libraries and government offices. The noise analysis, along with other aspects of the environmental review, were then subject to comment and review by several overseeing agencies and outside parties as prescribed in the NEPA. Comments were collected and transcribed directly in public hearings, in writing through comment forms and free-form correspondence. The FAA and EPA provided feedback and lists of required changes during the phase.

1999 through 2002 were spent strengthening areas of the EIS and addressing concerns raised during the public comment period. Most of these concerned technical confusion about the noise exposure, intended fleet mix, operational capabilities of the runway, and alternatives available to runway construction. The finalize EIS was released in the summer of 2012 [24]. In a final review process, the EPA mandated new mitigation measures and accountability mechanisms to ensure that the concessions to community noise concerns raised in the EIS were followed in practice [23]. The FAA issued a Record of Decision approving this amended EIS in 2012, allowing the project to continue to final design and construction phase. The formal environmental process mandated by FAA Order 1050.1E required 8 years for completion in the process, resulting in often-contentious negotiations and ultimate compromises based on quantitative noise analysis procedures.
Outcomes

Runway 14/32 opened for operations in 2006 with little fanfare [18]. After years of debate, including a decade-long effort to generate acceptable environmental policies and mitigations, Massport achieved a highly-visible victory in the form of an expanded runway layout. However, no stakeholder in the negotiation was entirely victorious, as significant operational restrictions on the runway were included as part of the final approval. With respect to noise specifically, recurring analysis in collaboration with community representatives are now required to ensure compliance with EIS mitigations. While current traffic levels do not meet the near-capacity levels last seen in the 1990s, the new runway is expected to serve an increasingly-important role as aircraft movements increase in future years.

Case Study 2: Greener Skies over Seattle

NextGen is an umbrella title covering a major modernization effort in the United States National Airspace System. Modernization programs fall into a variety of categories, although the general concept of most is to leverage modern information technology for improved cockpit awareness, tactical traffic control, and strategic flow management. One of the key technologies in NextGen are Performance-Based Navigation (PBN) approach and departure procedures. These procedures use GPS-defined routes with high-fidelity cockpit avionics to allow aircraft to follow precise routes, including smooth curving tracks with vertical guidance. While approach procedures using this new technology have been demonstrated in mountainous terrain in various locations around the world, the introduction to large airports with conventional procedures is a recent development [25]. “Greener Skies over Seattle” is a trial program for a special type of PBN approach that reduces fuel burn and community noise exposure relative to traditional routes. The noise analysis technique shows the current methods used for low-impact procedural changes, and the potential benefit by expanding the usefulness of Categorical Exclusions.

Background

The first type of PBN procedures developed were classified as Required Navigation Performance, Authorization Required (RNP-AR) procedures. These procedures require a certifiable level of navigation accuracy, method for ensuring procedural compliance, and special crew training prior to operation. The primary difference between RNP-AR procedures and more traditional Area Navigation (RNAV) procedures is the precise definition of turning segments in RNP-AR as well as a tighter for navigational accuracy. The original application of RNP was to allow precise descents into mountainous terrain during instrument conditions. Conventional approaches had very high minimums to allow for visual tracking of the landing runway and terrain, whereas RNP-AR approaches were meant to allow descent on instruments with full navigational confidence. Alaska Airlines, in cooperation with Naverus (now GE Aviation), developed the first such approach in 1996 for Runway 26 in Juneau, Alaska. The need for such an approach is illustrated in Figure 13 – the approach requires a descent through a channel with rising terrain on either side of the flight path, as well as a 30-degree offset turn 500 feet above touchdown height.
Naverus and other companies collaborated with several aviation authorities around the world to establish RNP-AR approaches at some of the most geographically-challenging runways for conventional approaches. However, the architects of NextGen also recognized the potential for RNP to fine-tune approach paths for flow management and noise control regions. Basic RNAV had already been demonstrated as an effective method for concentrating flight paths reliably as shown by a series of departure radar tracks in Figure 14. RNP procedures, with their precise ground-track control and repeatability, could potentially be used to concentrate flights in this manner over low-impact geographic regions while simultaneously shortening average approach track length.

The FAA chose Seattle as a testbed for implementation of RNP-AR procedures in congested terminal-area airspace. Several factors highlighted Seattle’s suitability for this project. First, there was enough traffic into the airport to lead to mixing of RNP and non-RNP traffic but not enough to cause significant system disruption in the event of integration problems. Secondly, Alaska Airlines was the dominant airline serving the airport. Due to earlier development in Alaska, many aircraft and pilots were already trained in RNP-AR procedures. Therefore, the implementation learning and cost curve at Seattle was lower than at other possible domestic US airports [26].
Figure 15. Conceptual illustration showing new curving RNP flight paths into Seattle (Figure: FAA)

Figure 15 shows one of the attractive attributes for RNP procedures compared to conventional radio-based methods. By flying curved paths, it becomes possible to follow noise-insensitive geographic features such as bodies of water while shortening overall approach path length. This is highly attractive from a fuel burn and community relations perspective. However, the details of noise and environmental impact were still required to be quantified using standard FAA reporting procedures. Many community members were already organized and highly alert due to debate over a contentious new runway project at Seattle-Tacoma International Airport that had recently opened in 2008.

**Players**

Most of the same types of stakeholders from the Logan Airport Runway 14/32 project were also present in the Greener Skies over Seattle program, although often with different interests and different stakes. The program was different from construction projects in that the new procedures were projected to cause a net decrease in noise relative to the no-action case, meaning that the burden of proof and topics of debate change compared to the ‘new runway’ case.

**FAA**

In the case of Greener Skies over Seattle, the FAA was the primary stakeholder and proponent of the project. Aside from achieving operational and environmental savings in Seattle, one of the key goals of the project was to establish feasibility for RNP procedures in congested shared-use airspace. With successful implementation of the new RNP approaches into Seattle, the FAA would have a stronger handle on remaining challenges to procedural rollout elsewhere and NextGen implementation as a whole. The FAA also saw the program as a test ground for political and environmental strategies on NextGen procedural implementation. Air Traffic Controllers were also central to this implementation process, since their expertise and support was required for complex mixed operations between RNP and conventional operations that would characterize the program and all future operations.

**Port of Seattle**

The Port of Seattle, the operating authority for the airport, was directly responsible for retaining consultants and working with partner airlines to grow support for the new procedures. The Port had a central role in noise-related concerns from the new approaches, particularly during the EA process which became unexpectedly controversial and required outreach by the Seattle-Tacoma International Airport noise office together with regional FAA officials.
Alaska Airlines

Alaska Airlines was the operator representative on the project, helping ensure that procedural integration was performed in a useful way and that pilot training matched the new procedures. The airline was an early adopter of cockpit technologies allowing RNP-AR approaches, including advanced flight management systems and head-up displays. Perhaps most importantly, the airline and its pilots served as an operational bellwether for the procedures once they became operational, providing direct feedback to the Port of Seattle and the FAA about day-to-day feasibility of the complex new procedures.

Community

The role of the community in the Greener Skies over Seattle perhaps best characterized by clarification rather than direct contention. The environmental assessment prepared for the project indicated that the majority of neighborhoods would see no noise change due to the new procedures, while a small subset of neighborhoods would experience a DNL increase of some 0.9 dB (well below the threshold of 5dB used by the FAA to signify major change in noise regimes below 65db). Essentially, the expected community impact was a net noise reduction and improved air quality for the vast majority of citizens. However, the FAA was unclear about the significance of RNP’s flight path concentration on those communities directly under the new procedures who previously experienced scattered overflights due to radar vectoring. Due to a lack of community hearings and publicity, this resulted in a relatively strong and swift community backlash over the initial environmental assessment until further clarifications were provided.

Noise-Specific Environmental Process

The Environmental Assessment for the Greener Skies over Seattle program followed industry standard procedure to ensure compliance with FAA Order 1050.1E, but also established new methodology to facilitate future RNP implementations around the country. In essence, the Port of Seattle was required to generate an Environmental Assessment despite the categorical exclusion for RNP approaches in the FAA Modernization and Reform Act of 2012. The text of that act states that:

*Any navigation performance or other performance based navigation procedure developed, certified, published or implemented that, in the determination of the Administrator, would result in measurable reductions in fuel consumption, carbon dioxide emissions, and noise, on a per flight basis, as compared to aircraft operations that follow existing instrument flight rule procedures in the same airspace, shall be presumed to have no significant effect on the quality of the human environment and the Administrator shall issue and file a categorical exclusion for the new procedure.* [27] § 213(c)(2)

Therefore, while Congress clearly intended a categorical exclusion to exist for projects exactly like Greener Skies over Seattle, the legal wording is not sufficient to allow for immediate adoption. For example, while a new RNP approach procedure may reduce noise for most people, it will almost certainly expose new residents to overflight compared to existing flight paths. The Port of Seattle’s consultants and RTCA, a rulemaking agency for the FAA, agreed to use the Greener Skies over Seattle to help develop accepted definitions and analytical methods to determine “measureable reductions... on a
per flight basis”. This would be accomplished under the framework of a traditional Environmental Assessment, with the intention of providing a simplified framework for future approaches to be developed under the faster and cheaper categorical exclusion.

As with most traditional noise analyses, the first step in the noise assessment was a forecast of new traffic distributions given expected flight paths, aircraft mix, and demand levels. The flight track inputs are shown in Figure 16. The Greener Skies over Seattle program included 24 proposed RNP approach paths for various runway configurations at the airport. Each configuration was analyzed independently.

![Figure 16. Forecast approach paths after implementation of Greener Skies over Seattle showing southerly flow runway configuration (Image: [28])](image)

The unique and novel feature of this environmental assessment was the need to associate and report each census block with its no-action and proposed-action DNL level. In this manner, the number of people who experience reduced noise and the number who experience increased noise could be tabulated and presented more clearly than with traditional DNL contours. Figure 17 shows the absolute noise level expected in the proposed-action case, while Figure 18 shows the census blocks exhibiting and increase or decrease in noise as a result of the change. The concept recommended by the RTCA to implement the categorical exclusion for RNP approaches is to tabulate the number of people who experience a DNL impact greater than 45dB due to aviation activity before and after a proposed procedural change. With a net positive number of people experiencing a decrease in noise, a procedure is qualified for the categorical exclusion [17].

The analytical and graphical techniques for this new metric were developed in the Greener Skies over Seattle environmental analysis, although not reported directly in the environmental assessment. The program was found to qualify for the categorical exemption under the proposed RTCA standard. 24,418 people would see an increase in noise as a result of the change, while 105,738 would see a decrease, resulting in a net noise reduction for 81,320 people [17]. The areas with increased DNL exposure are directly underneath the flight paths, reflecting the concentration of arrival corridors.
Figure 17. Absolute noise levels expected after implementation of Greener Skies over Seattle with grid-point analysis instead of traditional contours (Image: [28])

Figure 18. Census blocks with color-coded change in DNL due to Greener Skies over Seattle (red indicates increase in noise, green indicates decrease in noise, otherwise no change) (Image: [28])
Outcomes

The environmental assessment process for the Greener Skies over Seattle shows an effective collaborative noise planning process, with extensive buy-in from a variety of stakeholders. Alaska Airlines operated trial approaches in June 2012. The Greener Skies over Seattle Environmental Assessment was accepted by the FAA in November of 2012, followed shortly by operational implementation of the new procedures. Community acceptance of the new procedures was generally positive following multiple forums and meetings to clarify the magnitude of expected impacts. Other airlines are seeking approval to use the arrival routes, which reduce flight track distance considerably over traditional vectored approaches. Lessons learned in the design of the Greener Skies RNP procedures are being used in RNP implementation at many other major airports nationwide.

The categorical exclusion from environmental assessment remains a key focus area for the FAA and airport authorities. Once a precedent of successful categorical exclusion RNP implementation has been established, the pace of NextGen development in the United States will increase. While the Greener Skies over Seattle environmental assessment helped establish the necessary analytical methods, the full impact of the categorical exclusion will likely not be felt until its legality has been tested in court. Airport authorities are generally reluctant to be the first to invoke the exception for this reason.

Conclusions

Aircraft noise has become central to airport planning and operations since the passage of NEPA in 1969. In response to this legislation, the FAA has established standards for analysis and noise program implementation to ensure equitable consideration of community concerns as well as the practical necessities of airport operation. It is widely acknowledged that aircraft noise has impacts on health, property value, and quality of life. Population growth in the vicinity of airports puts continued pressure on airport authorities to address community discontent, although this must be balanced with operator demands for increased capacity and streamlined operations. Airport operators and regulators are recognizing this interconnected, compromise-driven landscape and have begun to implement collaborative decision-making processes in noise planning and analysis.

The two case studies presented here show the old and new paradigm for community relations in noise analysis. While the infrastructural scope of the Boston Logan Airport airside improvement program was much larger than the procedural modifications included in Greater Skies over Seattle, the net benefit of both achieve some level of parity. The process of EIS analysis, drafting, editing, and approval in a hostile community environment was shown to be one of the primary timetable bottlenecks for the Boston project. For Seattle, the process of the environmental assessment was actually extended beyond the minimums required to establish precedent for future analyses. Further refinement and adoption of the RNP procedure categorical exclusion could have a major impact on the pace of NextGen implementation.

One issue with the current noise analysis landscape is the reliance on DNL as the primary comparison metric, with maximum SPL playing a minor roll. While it is logical to view noise impact on
aggregate, the arbitrary night-time noise penalty and use of A-weighted frequency filtering does not necessarily reflect actual annoyance response to noise from the community. The ultimate objective of noise mitigation is to minimize annoyance, so an appropriate frontier for further research on the noise problem is investigation of annoyance metrics and correlating factors.

Works Cited


