Project 003 Cardiovascular Disease and Aircraft Noise Exposure

Boston University

Project Lead Investigator

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University Participants

Boston University (BU)

- PIs: Prof. Jonathan Levy (university PI), Prof. Junenette Peters (project PI)
- FAA Award Number: 13-C-AJFE-BU-016
- Period of Performance: October 1, 2020 to September 30, 2021

Massachusetts Institute of Technology (MIT)

- Sub-PI and Co-I: Prof. R. John Hansman, Dr. Florian Allroggen

Tasks (Performance Period)

Related to 2018 FAA Reauthorization, Section 189, Tasks 1–3

1. Write up and publish final results of analysis of hypertension and aircraft noise exposure.
2. Generate results for supporting analyses.
   a. Trends of aircraft noise exposure (preliminary)
   b. Sociodemographic patterning of aircraft noise exposure (final)
3. Generate preliminary results of analysis of sleep quantity and quality and aircraft noise exposure.
4. Generate preliminary results for cardiovascular disease (CVD) and aircraft noise exposure.

Related to 2018 FAA Reauthorization, Section 189, Task 4

5. Develop a model for measuring change in business activities attributable to aircraft noise exposure, prototyping a model city.

Project Funding Level

Total funding (three-year funding): $1,729,286
Matching: $1,729,286
Source of matching funds: Nonfederal donors to the Nurses’ Health Study (NHS), Health Professional Follow-up Study (HPFS), and Women’s Health Initiative (WHI) cohorts.

Investigation Team

Junenette Peters, PI, Boston University
Dr. Peters is responsible for directing all aspects of the proposed study, including study coordination, design and analysis plans, and co-investigator meetings.

Jonathan Levy, Boston University
Dr. Levy will participate in noise exposure assessment and provide expertise in the area of predictive modeling and air pollution.

Francine Laden, Jaime Hart, and Susan Redline, Harvard Medical School/Brigham and Women's Hospital
Dr. Laden is our NHS and HPFS sponsor for this ancillary study. Dr. Hart will assign aircraft noise exposures to the geocoded address history coordinates of each cohort member. Dr. Laden and Dr. Hart will also assist in documenting data from the NHS and HPFS based on their previous experience in air pollution and chronic disease outcome research in these cohorts and in appropriate analyses of hypertension and cardiovascular outcomes. Dr. Redline will lead efforts related to noise and sleep disturbance in the NHS and WHI.

John Hansman and Florian Allroggen, Massachusetts Institute of Technology
Dr. Hansman will participate in the economic impact assessment and will provide expertise on analytical approaches for quantifying noise. Dr. Allroggen will perform an economic impact assessment based on his expertise in analyzing the societal costs and benefits of aviation.

Project Overview

Exposure to aircraft noise is "the most readily perceived environmental impact of aviation" in communities surrounding airports (Wolfe et al., 2014). Exposure to aircraft noise has been associated with physiological responses and psychological reactions (Bluhm & Eriksson, 2011; Hatfield et al., 2001), including sleep disturbances, sleep-disordered breathing, nervousness, and annoyance (Hatfield et al., 2001; Rosenlund et al., 2001). Recent literature, primarily from European studies, provides evidence of a relationship between aircraft noise and self-reported hypertension (Rosenlund et al., 2001), increased blood pressure (Evrard et al., 2017; Haralabidis et al., 2008; Haralabidis et al., 2011; Jarup et al., 2008; Matsui et al., 2004), antihypertensive medication use (Bluhm & Eriksson, 2011; Floud et al., 2011; Franssen et al., 2004; Greiser et al., 2007), and incidence of hypertension (Dimakopoulou et al., 2017; Eriksson et al., 2010). However, the extent to which aircraft noise exposure increases the risk of adverse health outcomes is not well understood. Impacts related to annoyance have been empirically studied using the stated preference approach (Bristow et al., 2015) and the revealed preference approach, which often relies on analyses of house prices (Almer et al., 2017; Kopsch, 2016; Wadud, 2013). Although the impacts of aircraft noise on individuals are well understood, little evidence has been presented on the impact of aircraft noise exposure on businesses in communities located beneath flight paths. Section 189 of the 2018 FAA Authorization has called for a study on the potential health and economic impacts attributable to aircraft overflight noise.

The goal of this ongoing project is to examine the potential health impacts attributable to noise exposure resulting from aircraft flights; this project will leverage ongoing work within ASCENT to respond to Section 189. This study aims to assess the potential association between aircraft noise exposure and outcomes such as sleep disturbance and elevated blood pressure. The study will leverage existing collaborations with well-recognized and respected studies that have followed over 250,000 participants through the course of their lives to understand factors that affect health. These studies include the NHS and HPFS. Furthermore, this work is aligned with an ongoing National Institutes of Health (NIH)-funded effort to examine these associations in the WHI. The research team will leverage aircraft noise data for 90 U.S. airports from 1995 to 2015, as generated using the Aviation Environmental Design Tool (AEDT); these data will then be linked to demographic, lifestyle, and health data for the participants of long-term health studies. These studies provide considerable geographic coverage of the United States, including all the geographic areas specified in Section 189.

This work will also respond to the aspect of Section 189 calling for the study of economic harm or benefits for businesses located in communities underneath regular flight paths. The study will involve a first-of-its-kind empirical assessment of the economic impacts on businesses located beneath flight paths at selected U.S. airports. Such impacts are expected to be driven by (a) potential positive economic impacts related to the airport and its connectivity, and (b) environmental impacts such as noise, which may reduce the revenue and productivity of businesses beneath flight paths. The team will evaluate whether such impacts can be empirically identified while considering economic outcome metrics such as the gross domestic product (GDP), employment, and revenue.

The overall aims for the three-year project are as follows:

- Perform Tasks 1–3 [*Sec. 189. (b)(1–3)*]: Potential health impacts attributable to aircraft overflight noise.
    - Investigate the relationship between aircraft noise exposure and the incidence of hypertension in the NHS and HPFS, accounting for other individual- and area-level risk factors.
    - Investigate the relationship between aircraft noise exposure and the incidence of cardiovascular disease (CVD) in the NHS and HPFS cohorts and determine whether sufficient data exist to prove a causal relationship.

    - Determine whether a relationship exists between annual average aircraft noise exposure and general sleep length and quality in the NHS and the Growing Up Today Study (GUTS) and report whether sufficient data exist to prove a causal relationship.
    - Evaluate the potential relationship between residing under a flight path and measures of disturbed sleep in the WHI WHISPER sub-study.
- Perform Task 4 [*Sec. 189. (b)(5)*]: Potential economic impacts attributable to aircraft overflight noise.
    - Model noise exposure before and after the introduction of area navigation (RNAV) procedures on the basis of FAA flight trajectory data.
    - Combine noise data with yearly county-level data from the Bureau of Economic Analysis (BEA) (e.g., GDP, employment) and with city-level statistics for the years 2007, 2012, and 2017 from the Economic Census (e.g., revenue, employment).
    - Compare economic outcomes using state-of-the-art econometric approaches while controlling for regional and national economic trends.
    - Evaluate whether the spatial resolution of the available data can significantly impact the study results.

Task 1 - Generate Final Results for Analyses of Aircraft Noise and Hypertension

Boston University

Objective

To generate final results of analyses of aircraft noise (day-night average sound level [DNL]) and hypertension.

Research Approach

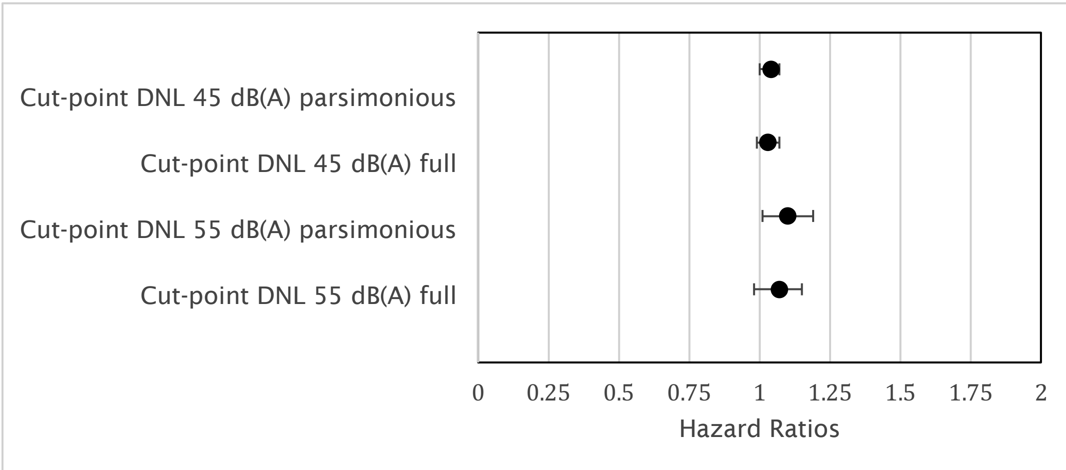
We intersected modeled noise exposure surfaces for 1995, 2000, 2005, 2010, and 2015 with geocoded addresses of the participants over the follow-up period. We selected a large set of a priori variables to be examined as confounders and/or effect modifiers and used time-varying Cox proportional hazards models to estimate hypertension or CVD risks associated with time-varying aircraft noise exposure, while adjusting for both fixed and time-varying covariates. We also performed a sensitivity analysis to address potential biases.

Milestones

Generate and submit final results from analyses of aircraft noise (DNL) and hypertension for publication (October 2021).
Present to the Airport Council International (ACI) (March 2021).
Present at the International Commission on Biological Effects of Noise (ICBEN) Congress (June 2021).

Major Accomplishments

- Generated final results of analysis of aircraft noise (DNL) and risk of hypertension.
- Drafted manuscript reporting results of analysis of aircraft noise and hypertension.
- Gained all Harvard/BWH Channing manuscript approvals including undergoing scientific, program, and technical reviews. We also so submitted manuscript for FAA review.
- Submitted the manuscript to a peer-reviewed journal.
- In response to journal reviewer comments, reevaluated the inclusion of variables that could be mediators or colliders (variables that could introduce bias because of their relationships with other variables). We ended up with three models – crude, parsimonious (multivariable excluding potential mediators and colliders), and fully adjusted. The crude model controlled for age and calendar year; the parsimonious model additionally controlled for race, physical activity, smoking status, alcohol use, DASH (dietary approaches to stop hypertension), spouse's education attainment, neighborhood-level socioeconomic status (nSES), and region of residence; and the fully adjusted model additionally controlled for menopausal status, family history of hypertension, and body mass index (BMI).
- We generated results for NHS (original) and NHS II and performed a meta-analysis combining the results from the two cohorts (Figure 1).
- Presented research at the ACI Meeting.
- Presented research at the ICBEN Congress.



[1]Parsimonious model: Adjusted for age, calendar year, race, physical activity, smoking status, alcohol use, DASH (dietary approaches to stop hypertension), spouse's education attainment, neighborhood-level socioeconomic status (nSES), and region of residence.
[2]Fully-adjusted model: Adjusted for age, calendar year, race, physical activity, smoking status, alcohol use, DASH, spouse's education attainment, nSES, region of residence, menopausal status, family history of hypertension, and body mass index (BMI).

Figure 1. Hazard ratios (95% confidence intervals) for hypertension associated with aircraft noise in the Nurses' Health Study (NHS) and NHS II (meta-analysis), comparing results for day-night average sound level (DNL) ≥45 dB with those for DNL <45 dB and for DNL ≥55 dB with those for DNL <55 dB in the parsimonious[1] and fully adjusted[2] models.

Interpretation using the DNL 55 dB cut-point as an example: In the combined parsimonious model, using a DNL 55 dB cut-point, participants in NHS and NHS II exposed to levels ≥ DNL 55 dB had a 10% increased risk of hypertension compared to participants exposed to levels < DNL 55 dB, with a 95% confidence interval (CI) of 1% to 19%. In the combined fully adjusted model, participants exposed to ≥ DNL 55 dB had a 6% increased risk (95% CI: −2%, 15%) compared with the unexposed. The hazard ratios were relatively stable across the sensitivity analyses including controlling for air pollution. There was an indication that smoking modified the relationship between noise and hypertension.

Task 2 - Generate Preliminary Results from Supporting Analyses: (a) Trends in Aircraft Noise Exposure and (b) Sociodemographic Patterning of Aircraft Noise Exposure

Boston University

Objective

To understand changes in exposure that will facilitate our interpretation of time-varying exposure measures in noise-health analyses and to understand sociodemographic patterning of noise exposure that may confound or modify potential associations of noise and health.

Research Approach

For (a) (Noise Trend), we overlaid noise contours for 2000, 2005, 2010, and 2015 and census block data from the U.S. Census Bureau and American Community Surveys for 2000, 2010, and 2015 in a geographic information system to estimate population changes within noise levels. We will utilize linear fixed-effects models to estimate changes in the sizes of exposure areas based on U.S. census regions/divisions with DNL values ≥65 dB or ≥55 dB. For (b) (Sociodemographic Patterning), we described the characteristics of populations exposed to aviation noise by race/ethnicity and income/education using the U.S. Census Bureau and American Community Survey for 2010 and performed univariate and multivariable hierarchical and multinomial analyses.

Milestones

- Perform supporting analyses characterizing aircraft noise trends and sociodemographic patterns of exposure to aviation noise.
- Submit manuscript reporting results of sociodemographic patterns of exposure to aviation noise.

Major Accomplishments

- Overlaid noise contours for 2000, 2005, 2010, and 2015 and census block data from the U.S. Census Bureau and American Community Surveys for 2000, 2010, and 2015.
- Evaluated the sociodemographic pattern of exposure to aircraft noise over time (2000–2015).
- Evaluated geographic and airport characteristics as predictors of patterns of exposed area over time.
- We determined social patterning of aircraft noise exposure by race/ethnicity and income/education for 2010 using univariate and multivariable analysis (mixed effects, hybrid, and Bayesian approaches) at three DNL cut-points: 45 dB, 55 dB, and 65 dB. Preliminary results are presented in Table 1 (multivariable mixed effects) for airports with at least 100 census block groups at the DNL 65 dB cut-point with and without controlling for distance to the airport.
- In response to journal reviewer/editor comments, we also ran a multivariable model by category of noise exposure DNL 45 to <55 dB, 55 to <65 dB, and ≥65 dB compared with DNL <45 dB (multinomial analysis).

Table 1. Within-airport odds ratio for block group exposure to day-night average sound level (DNL) ≥65 dB (for 15 airports with ≥100 block groups within the study area) for a 10% increase in percent of block group with characteristic using multivariable hybrid mixed-effect logistic model with random intercept by airport.

(N airports = 15; N block groups = 4,031; N block groups exposed = 58)	Main Model[1]	Main model + adjustment for distance to airport
Variables	Odds Ratio (95% CI)	Odds Ratio (95% CI)
% Race/Ethnicity		
Non-Hispanic Black	0.96 (0.89, 1.04)	0.99 (0.90, 1.07)
Non-Hispanic Asian	0.44 (0.30, 0.66)	0.51 (0.34, 0.77)
Hispanic	1.09 (0.96, 1.23)	1.08 (0.96, 1.23)
Non-Hispanic Other	0.82 (0.54, 1.25)	0.88 (0.57, 1.35)
Non-Hispanic White	Reference	Reference
% Education		
< High school diploma or GED	1.08 (0.89, 1.30)	1.10 (0.91, 1.33)
High school diploma or GED	1.11 (0.93, 1.32)	1.15 (0.96, 1.38)
> High school diploma or GED	Reference	Reference
% Household Income		
<$25k	0.99 (0.84, 1.15)	1.01 (0.86, 1.18)
$25k to <$50k	1.10 (0.92, 1.31)	1.13 (0.94, 1.34)
$50k to <$75k	1.17 (0.95, 1.43)	1.20 (0.97, 1.49)
≥$75k	Reference	Reference

[1]Main model adjusted for variables on race/ethnicity, education, household income, and airport.

Task 3 - Assess Suitability of Data on Sleep Quality and Develop a Noise-Sleep Analysis Plan

Boston University

Objective

To identify sleep measures that may be used to evaluate potential associations between noise and sleep outcomes and to perform preliminary analysis of aircraft noise (DNL) and nighttime equivalent sound levels and identified sleep outcomes.

Research Approach

We reviewed the available measures of sleep quality and sleep quantity for the NHS to determine their timing and frequency and their relationship to the timing of the noise exposure data. We also determined which measures were relevant to the average exposure measures. Suitable measures were found, so we developed an analysis plan and presented it to the NHS and HPFS committees. We selected a large set of a priori variables to be examined as confounders and/or effect modifiers and are using generalized estimating equations to estimate odds from repeated measures of sleep insufficiency over multiple survey years and using conditional logistic regression models of sleep quality to estimate odds for the one survey year.

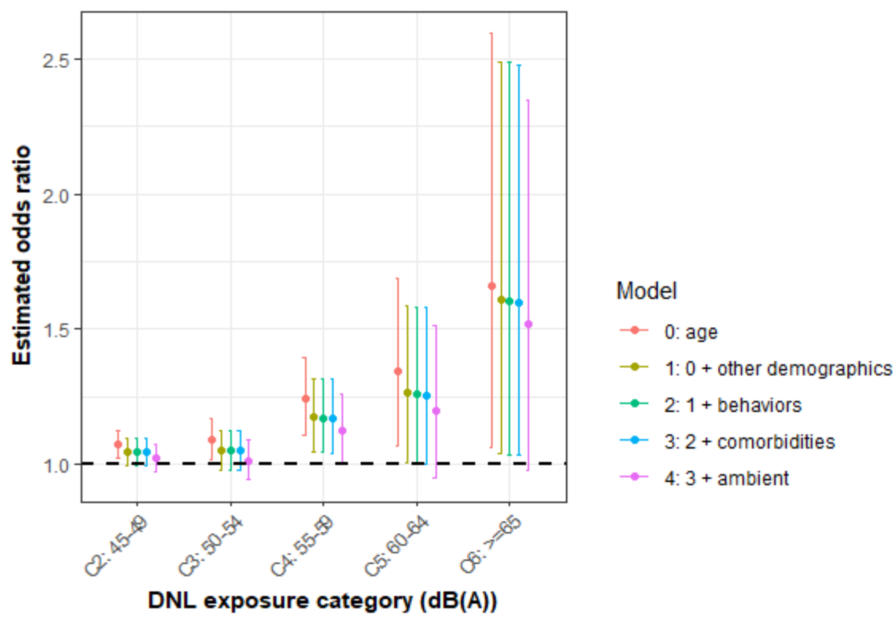
Milestone

Preliminary results of analysis of DNL and nighttime aircraft noise and sleep quantity and sleep quality in NHS (August 2021)

Major Accomplishments

- Determined timing of sleep measures relevant to exposure for NHS (original).
- Produced descriptive statistics of sleep measures and numbers exposed by measure in NHS.
- Determined relevant confounders and effect modifiers.
- Performed preliminary analysis on noise and sleep quantity (insufficiency) and sleep quality.
- Requested access to data on other environmental factors that could confound or modify the relationship between noise and sleep - light at night and greenness. Incorporated these data and tested variables.
- Wrote and submitted abstract on noise and sleep quantity to International Society of Environmental Epidemiology (ISEE).
- Presented results of analysis at ISEE Conference (example of preliminary results in Figure 2).

Figure 2 shows the odds of sleep insufficiency (defined as ≤6 hr/night) by category of noise exposure (DNL) for models controlling for age and sequentially further adjusted as indicated with (1) other demographics: U.S. region of residence, race, living alone, spouse's education; (2) behaviors: smoking status, alcohol consumption; (3) comorbidities: diabetes, hypertension; and (4) ambient environmental: particulate matter of size 2.5 µm or smaller ($PM_{2.5}$), greenness (normalized difference vegetation index, NDVI), light at night (LAN).



$N_{short\ sleep}$	3479	1692	685	159	39
N_{total}	11616	5526	2014	461	100

Figure 2. Potential dose-response relationship between DNL (5 exposure categories compared to the reference category <45 dB(A)) and sleep insufficiency.

Task 4 - Develop an Analysis Plan for Cardiovascular Disease and Aircraft Noise and Generate Descriptive Statistics

Boston University

Objective

To generate an analysis plan for studying the potential relationship between CVD and aircraft noise and perform preliminary analyses.

Research Approach

We developed an analysis plan for studying CVD and aircraft noise and gained approval from the NHS and HPFS oversight committees. We designed the statistical analysis and selected a large set of a priori variables to be examined as confounders and/or effect modifiers. We compiled appropriate data sets and ran descriptive statistics. We are using time-varying Cox proportional hazards models to estimate CVD risk associated with time-varying aircraft noise exposure.

Milestone

Preliminary results of analysis of aircraft noise and CVD (August 2021).

Major Accomplishments

- Updated the person-time of people free of CVD at baseline (1995) and number of cases (Table 2).
- Incorporated updated NHS and NHS II data relevant to this analysis.
- Ran preliminary analysis of noise and CVD risk for NHS (Figure 3).

Table 2. Number of CVD cases, including number of exposed cases at different exposure cut-points. DNL = day-night average sound level; NHS = Nurses' Health Study.

	NHS
Total CVD cases	**8,730**
Exposed cases	
≥DNL 45 dB	*599*
≥ DNL 55 dB	*87*
≥ DNL 65 dB	2

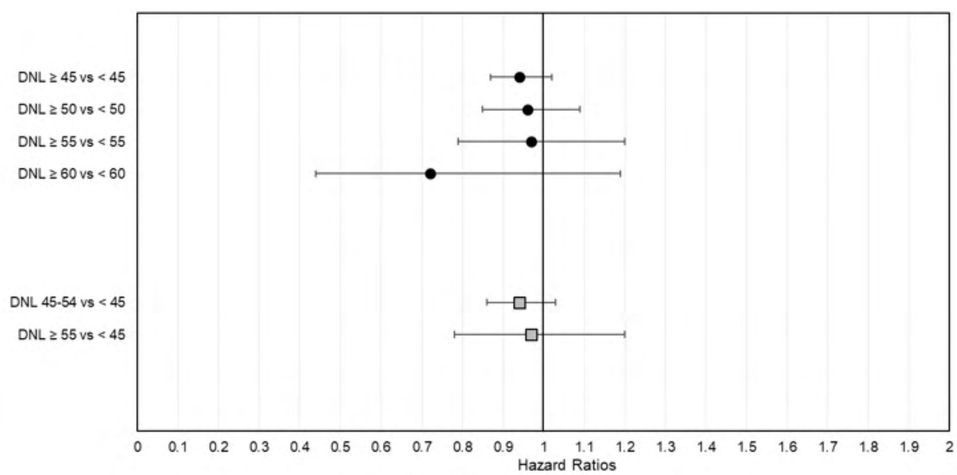


Figure 3. Hazard ratios (95% confidence intervals (CIs)) for CVD associated with aircraft noise in the NHS, comparing results for ≥DNL 45 dB with those for <DNL 45 dB and ≥ DNL 55 dB with those for < DNL 55 dB in crude models and in categorical variables comparing DNL 45-54 dB and > DNL 55 dB to those for < DNL 45 dB (all adjusting for age and calendar years).

Interpretation using DNL 55 dB as an example: In the crude models comparing exposure to DNL ≥55 dB, participants in NHS exposed to DNL ≥55 dB had a 3% decreased risk of CVD compared to participants exposed to DNL <45 dB, with a 95% confidence interval of −22% to 20%.

Task 5 - Develop a Model for Measuring Change in Business Activities Attributable to Aircraft Noise Exposure, Prototyping a Model City

Massachusetts Institute of Technology

Objective

To develop a model for measuring changes in business activities attributable to aircraft noise exposure and begin data analysis to assess potential impacts on business dynamics, controlling for confounding, prototyping one or two cities.

Research Approach

During the current reporting period, the economic impact of noise exposure changes was studied for Boston Logan Airport and Chicago O'Hare Airport. The methods centered on the difference-in-difference approach, which was applied to identify differences between changes in business trends before and after exogenous noise exposure changes such as the introduction of performance-based navigation (PBN) procedures at Boston Logan Airport or the opening of new runway infrastructure at Chicago O'Hare Airport.

The analyses included the following:

- Mapping changes in both noise trends and business activities, which gives insights into the geographical distribution of noise changes and changes in business activities.
- Correlation analysis, which was used to identify whether changes in aviation noise are strongly correlated with local trends in business activities.
- Treatment group analyses, which test whether regions with noise increases or decreases (treatment groups) show business trends that differ significantly from regions where no changes in noise exposure are observed. Treatment groups were defined using different noise change thresholds. In addition to using simple noise-increase and noise-decrease treatment groups, we also studied a set of geographically contiguous treatment groups, which would capture prevalent neighborhood trends).

Milestone

Empirical studies of the impacts of noise exposure changes on local business dynamics were completed for Boston Logan Airport and Chicago O'Hare Airport (September 2021).

Major Accomplishments

- Completed a review of the validity and internal consistency of high-resolution business data that is used to determine changes in economic outcomes; business data were cleaned and reorganized.
- Identified necessary noise data required for comparing between and within cities and determined the timeline for obtaining that data.
- In our preliminary case studies for Boston Logan Airport (BOS), no significant relationship between noise exposure and business dynamics has yet been found (see Figures 5 and 6).
- Ran a full set of analyses for Boston Logan Airport and Chicago O'Hare Airport (ORD). By way of example, we include here results for selected analyses of noise trends and changes in business activity in Figures 4 to 7.

Figure 4 shows changes in both noise exposure and local business dynamics (measured through the number of businesses) for Chicago O'Hare Airport. The mapping does not reveal a strong visible relationship between noise changes and changes in business dynamics. Figure 5 plots local changes in noise exposure and business activity, again revealing no clearly visible trends. Outliers were studied in detail to ensure that they are not case studies for situations in which strong impacts of noise on business activities must be suspected.

Figure 6 shows the results of empirical testing procedures, which were conducted to identify significant differences in business dynamics between treatment and nontreatment areas (see Research Approach for definitions). The results do not point toward any statistically significant differences, irrespective of the applied noise thresholds. The analysis was repeated for geographically contiguous treatment groups, which again did not yield significant results (see Figure 7).

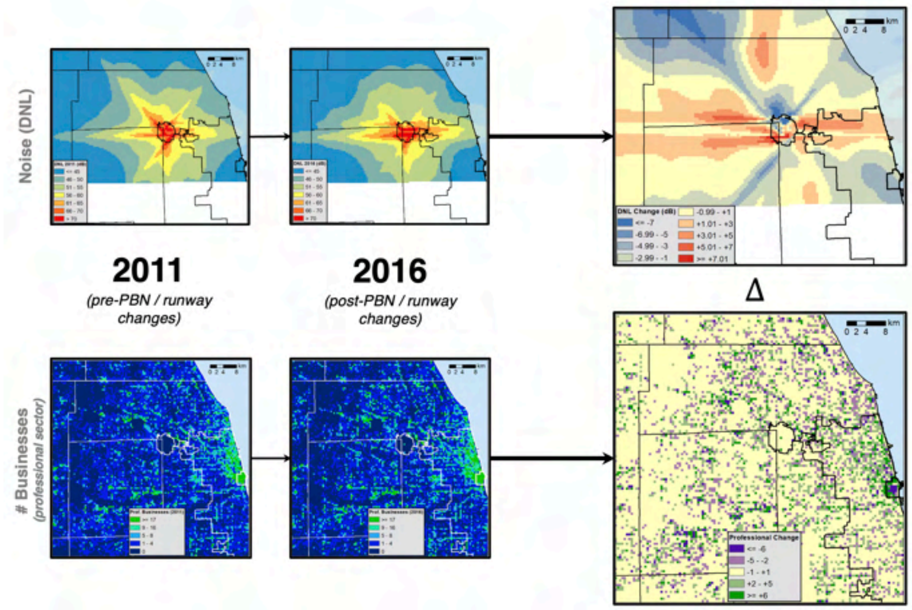


Figure 4. Geospatial analysis of changes in noise exposure and business activities for Chicago O'Hare Airport. PBN = performance-based navigation.

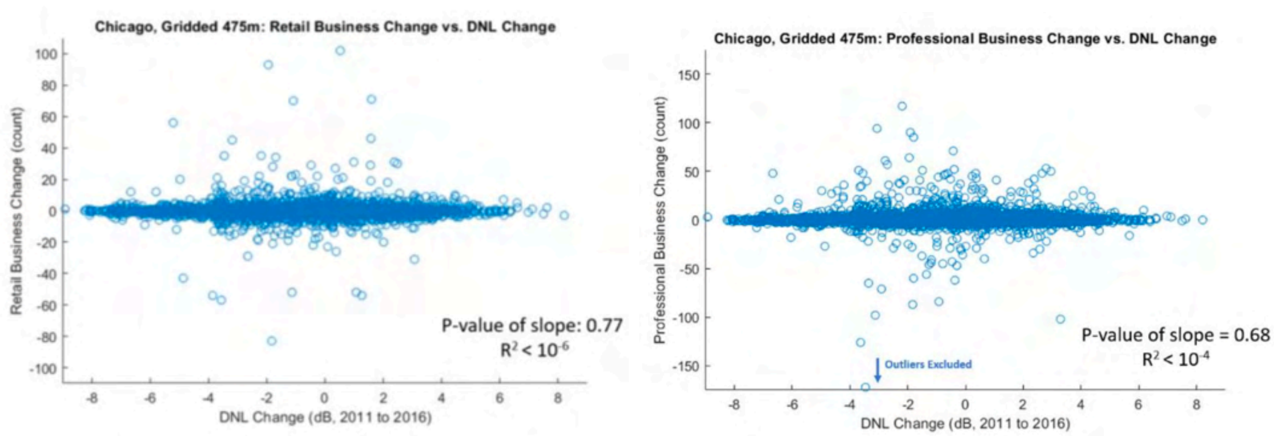
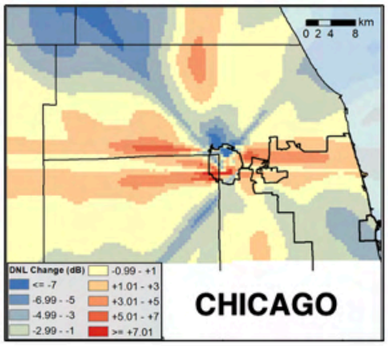


Figure 5. Correlation analysis of noise exposure changes and local business dynamics in the retail sector (left panel) and the professional business sector (right panel) for Chicago O'Hare Airport. DNL = day-night average sound level.



Nontreatment: Noise Change ≥ -1 and ≤ +1	Noise increase ≥ 1 dB	Noise increase ≥ 2 dB	Noise increase ≥ 4 dB	Noise decrease ≤ -1 dB	Noise decrease ≤ -2 dB	Noise decrease ≤ -4 dB
Mean: -0.15	Mean: -0.25 DoM: +0.10	Mean: -0.24 DoM: +0.09	Mean: +0.09 DoM: -0.24	Mean: -0.22 DoM: +0.07	Mean: -0.25 DoM: +0.10	Mean: -0.12 DoM: -0.03

Mean = Average change in business # by grid cell 2011-2016 * α < 0.1 ** α < 0.05
DoM = Difference in mean between control group vs. treatment group

Figure 6. Significance testing of business trends in treatment groups vs. control groups for the retail sector around Chicago O'Hare Airport.

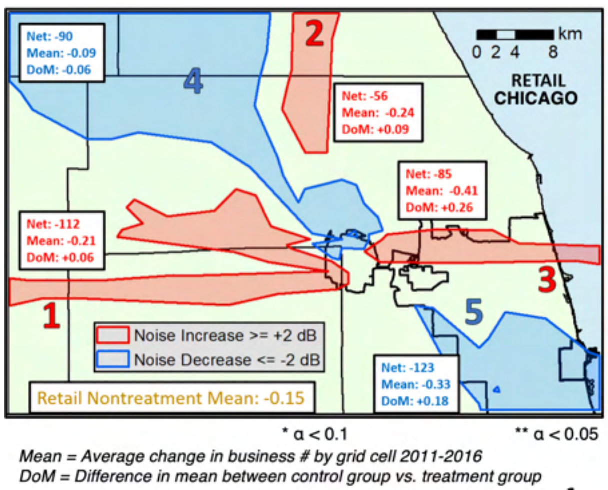


Figure 7. Significance testing of business trends in geographically contiguous treatment versus control groups for the retail sector around Chicago O'Hare Airport.

Publications

Bullock, C. (2021). Aviation effects on local business: Mapping community impact and policy strategies for noise remediation. [S.M. thesis, Massachusetts Institute of Technology].

Kim, C. S., Grady, S. T., Hart, J. E., Laden, F., VoPham, T., Nguyen, D. D., Manson, J. E., James, P., Forman, J. P., Rexrode, K. M., Levy, J. I., & Peters, J. L. (2021). Long-term aircraft noise exposure and risk of hypertension in the Nurses' Health Studies. Environmental research, 112195. Advance online publication. https://doi.org/10.1016/j.envres.2021.112195

Outreach Efforts

Presented on current progress orally during the ASCENT Spring Meeting (April 27–29, 2021) and during the ASCENT Fall Meeting (October 26–28, 2021).

Presented on "Associations between aircraft noise exposure and insufficient sleep in the US-based prospective Nurses' Health Study I cohort" at the International Society of Environmental Epidemiology (ISEE) conference, August 23-26, 2021.

Presented on "Long-term aircraft noise exposure and incident hypertension in national US cohort studies" at the International Commission on Biological Effects of Noise (ICBEN) Congress on June 15, 2021.

Presented on "Aircraft Noise and Health Research" to the Airport Council International (ACI) on March 23, 2021.

Awards

None.

Student Involvement

The dissertation of Chloe Kim (doctoral graduate, BU) included the development and implementation of statistical analyses on the noise and hypertension risk. Chloe Kim graduated in the fall of 2019 and is currently working for the Environmental Science, Policy, and Research Institute.

The dissertation of Daniel Nguyen (doctoral candidate, BU) includes a characterization of the temporal trends in aviation noise surrounding U.S. airports.

The research rotation of Stephanie Grady (doctoral student, BU) includes the development and running of statistical analyses on noise and cardiovascular event risk, which will continue as part of her dissertation. Stephanie also worked with Chloe Kim on noise and hypertension risk.

Carson Bullock (master's student, MIT) conducted economic impact analysis and graduated in the summer of 2021.

Plans for Next Period

(October 1, 2020 to September 30, 2022)

Related to 2018 FAA Reauthorization, Section 189, Tasks 1–3

- Assign noise exposure estimates to participants for nighttime equivalent sound level metrics to NHS II.
- Continue analyses to estimate the risk of CVD events associated with aircraft noise exposure.
- Complete analyses to evaluate the relationship between noise and sleep.
- Verify, document, and publish results.

Related to 2018 FAA Reauthorization, Section 189, Task 4

- Verify and document results.
- Consider analyses of additional airports.

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