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An evaluation of noise reduction strategies at large commercial airports in the United States: A policy analysis and framework classification

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AN EVALUATION OF NOISE REDUCTION STRATEGIES AT LARGE COMMERCIAL AIRPORTS IN THE UNITED STATES: A POLICY ANALYSIS AND FRAMEWORK CLASSIFICATION

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To my family for their endless support

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ABSTRACT

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Noise pollution from aircraft, specifically in the vicinity of airports as aircraft takeoff and land, is a problem that has been shown to have negative impacts on the welfare of humans, animals, and the surrounding environment. The problem may only become worse as air travel increases for cargo and passenger operations, populations increase, and the overall number of aircraft increase. Currently, guidance has been issued from the International Civil Aviation Organization on how to combat the issue of noise pollution through policy, both at that national regulatory level, and at the local airport level. This study evaluated the local airport policy implementation schemes at 132 Class B and Class C airports in the United States. A latent class analysis was used to determine that six different airport clusters existed, each with a different set of noise pollution mitigation strategies ranging from the implementation of only noise mitigation strategies specifically approved by the FAA (e.g., noise abatement procedures), to airports that invest millions of dollars in the community for soundproofing homes and schools in addition to fines for aircraft violating specific noise threshold limits set in noise monitoring sensors around a community. In addition to the latent class analysis, this study found that several characteristics of the airport and the local surrounding community (within 10 miles)

appeared to predict the potential policies that an airport might choose to implement. The region of the country in which an airport is located, and the population per square mile within ten miles of the center of the airport were significant predictors of the likelihood of an airport implementing a certain set of policies. Airports with larger population densities and located in the western portion of the United States, were more likely to belong to the cluster of airports that implemented a multitude of policy strategies than belong to the cluster of airports that sparsely implemented a few aircraft procedural policies.

CHAPTER 1. INTRODUCTION

This research presents a comprehensive study of noise mitigation strategies currently used at airports in the United States and provides understanding of how US airports realize and cope with noise pollution from aircraft. Identifying what airport communities are currently doing to reduce noise pollution, how airport noise policies vary from community to community, and why differences in noise mitigation policies at airports exist, may help guide policymakers in the future when addressing noise mitigation strategies and highlight areas where improvements are feasible. This chapter presents an overview and background of the topics included in this dissertation and the merits related to this study. A basic overview of the research project, defining the research question, the scope, and the significance of the study are addressed. Assumptions, limitations, and delimitations that are implicit to this study are also included.

1.1 Statement of the Problem

As more research of areas surrounding airports is being conducted, concern about noise pollution is increasing. The effects of noise pollution can disrupt environments of humans and animals. Health effects, physical and mental, attributed to aircraft noise are continuously being evaluated, and research shows that disruptive noise levels may harm human health. Haines et al (2002) examined the effects of test scores of students who attend school in the vicinity of the London Heathrow Airport and found that students subject to more aircraft noise had poorer reading performance scores than students not subject to aircraft noise. The researchers concluded that chronic noise exposure has an impact on mathematics and reading performance, but socioeconomic factors (i.e. class, defined by students eligible for free school meals) confounded the results. This suggested that levels of socioeconomic status and persons subjected to high levels of aircraft noise could be related (Haines et al., 2002). Haines et al. (2002) concluded that further research was necessary studying links between noise exposure and socioeconomic status.

In addition to academic performance, aircraft noise also affected the physical health of those exposed. In July 2010, a review of literature pertaining to health effects of aircraft noise was created through the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) project (Swift, 2010). This project concluded that serious adverse health consequences have been linked to aircraft noise, particularly at night. Two major health issues, hypertension and heart disease, were cited in several studies as potential health risks attributed to lack of sleep resulting from aircraft noise. Lack of sleep due to aircraft noise also has been shown to contribute to obesity and diabetes. Although many of these health issues can be attributed to noise in general, noise produced by aircraft is a contributing source (Swift, 2010).

Noise pollution is harmful to communities. Noise affects people and animals by filling what would otherwise be a quiet environment with unnatural, manmade noise at high intensity levels. Pepper, Nascarella, and Kendall (2003) state, “The two most important elements of noise exposure in wildlife are the proximity to the airport and the frequency of overflight" (p. 425). Animals rely heavily on their hearing to obtain food, evade predators, and reproduce. Loud aircraft noise may change their behavior patterns, potentially causing a lifelong change in behavior. Studies have shown that animals exposed to excessive noise typically exhibit a fright response, resulting in the animal attempting to escape the source of the noise. The habitat where the animal resides may affect its response to aircraft noise (Pepper et al., 2003). Animals may respond more aggressively around airports that are surrounded by large open fields, compared to airports that are located in busy urban environments. This is a result of the increased noise in open environments due to the lack of natural sound barriers in forests or urban areas (Pepper et al., 2003). Many airports have implemented environmental components to their noise reduction programs that describe airport procedures such as how to clear hazardous wildlife from the airport boundaries in an attempt to mitigate effects on natural animal habitats. It is important to understand the impact on animals because airports typically include large areas of undeveloped property that are home to many species of animals, including ground-based deer and foxes as well as many varieties of birds. If these animals become confused or aggressive they may wander onto airport surfaces impeding or colliding with aircraft, and endangering ground personnel (Pepper et al., 2003). Cleary and Dolbeer (2005) reported that wildlife strikes to aircraft resulted in deaths to over 100 people and caused a yearly $500 million in damage, with 74 percent of wildlife strikes occurring on airport grounds or within the immediate vicinity. Between 1960 and 2004, 18 of 19 large transport category aircraft severely damaged by wildlife occurred on airport grounds.

1.2 Research Questions

The purpose of this study is to determine the common noise policies and strategies that large commercial airports currently administer in the United States and then establish a predictive typology of those policies. The research questions are:

Research Question 1. What are the current noise pollution mitigation policy strategies utilized by large commercial airports in the United States and how frequently are they implemented?

Research Question 2. To what extent do airport location environments and local community demographic characteristics predict airport noise mitigation policies?

1.3 Scope

This study focused on examining noise mitigation policies and strategies implemented at commercial airports in the United States and it is limited to 132 Class B and Class C United States airports. These airports were examined because of they typically have the most aircraft operations, they typically operate continuously, and all aircraft are controlled by air traffic control. These airports have implemented a variety of noise pollution mitigation policies and the implementation status of each policy was determined by Boeing in 2011.

1.4 Significance of the Problem

The International Civil Aviation Organization initially began discussing concerns over aircraft noise in the late 1960s and early 1970s and the United States adopted aircraft noise regulations in 1969 (Yeowart, 1972). Since then, noise concerns have received intense scrutiny at the international level, resulting in the first set of international protocols in 1971, via Standards and Recommended Practices (SARPs), through the 16th Annex (Annex 16) to the Convention on International Civil Aviation of 1944 (International Civil Aviation Organization, n.d.). Expanding the scope of Annex 16 to incorporate the broad category of environmental protection, aircraft noise issues and standards became Volume I of Annex 16, passed by the ICAO Council in 1981 (International Civil Aviation Organization, n.d.).

With the expected future growth of the aviation industry worldwide, an effective and sustainable approach to aircraft noise mitigation is important. The term "noise" is commonly referred to as any unwanted sound. The disturbance from noise on an individual can be exacerbated by length of exposure time, time of day, physical surroundings, whether one has control over the source, etc. (Pennsylvania State University, 2014). The United States Environmental Protection Agency (EPA) also defines noise as unwanted or disturbing sound that interferes with normal actions. The inability to smell, see, or taste noise pollution provides an explanation as to why it might not receive the same scrutiny as water or air pollution (U.S. Environmental Protection Agency, 2015). A major component in the effect of noise is the distance one is located from the noise source (Janić, 2007, p.118). Each person has a different level of noise tolerance (Pennsylvania State University, 2014, 2014**).** While extensive research is conducted to improve aviation safety, because of the necessity of aviation in stimulating the global economy, the impact of increased aviation activity on a local community is often overlooked. Studies often fall short of fully understanding the true effects of noise disturbances on local residents at an individual community level. When local residents are disturbed by aircraft noise, the scientifically understood level of noise harm may be irrelevant because sensitivity to that noise is subjective. There is no one level of noise that determines a disturbance on an individual. Understanding what airport communities are currently doing, and how airport noise policies vary from community to community, may help guide policymakers in the future when addressing noise mitigation strategies and highlight areas where improvements are feasible. It may highlight key areas for future research and give future researchers an extra tool for more complete analyses.

1.5 Statement of Purpose

The purpose of this study was to understand the regulatory and strategic policies in place at commercial use airports in the United States aimed at controlling the noise production by aircraft that affects the surrounding airport communities. This study identified the common noise policies and strategies large commercial airports currently administered in the United States and then established a predictive typology of those policies. Identifying what airport communities are currently doing to reduce noise pollution, and how airport noise policies vary from community to community, and why variations in noise mitigation policies exist, may help guide policymakers in the future when addressing noise mitigation strategies and highlight areas where improvements are feasible.

This research examined how the management of US airports understand and cope with noise pollution from aircraft and it explored the relationships between noise policies at airports and the populations that surround airport communities. Recommendations for possible noise pollution mitigation solutions for airport communities are provided.

1.6 Definitions

For the purpose of clarity and simplicity, many unique and/or complex terms and phrases will be used in this dissertation and are defined as follows:

Stage – noise level output thresholds as described by ICAO standards and certified by the FAA. Certified levels range loudest to quietest and are designated stage 1 through stage 4 (U.S. Government Publishing Office, 2015).

Institution– the organizations and rules that structure the patterns of interaction within and across organizations (Ostrom, 2007)

Noise Monitor System– the formal structure of individual noise monitors throughout an airport community designed to record specific aircraft noise levels on a decibel scale (Rules and Regulations, 2009)

Noise Complaint– a documented report initiated by a member of an airport community to the local airport either by phone call or internet submission (Hume, Gregg, Thomas, & Terranova, 2003)

A-weighted decibel– The A-weighted Decibel (dBA) is the most common unit used for measuring environmental sound levels. It adjusts, or weights, the frequency components of sound to conform with the normal response of the human ear at conversational levels. dBA is an international metric that is used for assessing environmental noise exposure of all noise sources (Pennsylvania State University, 2016a)

EPNdB – effective perceived noise levels. A formula to measure noise, in A-weighted decibels that estimates a measure of loudness for an individual, adjusted for disturbances in environment and duration of noise (International Civil Aviation Organization, 2011)

DNL– a noise measure indicating day/night noise levels used to describe the average aircraft noise over a 24-hour period, typically an average day over the course of the year. DNL considers aircraft operations occurring between the hours of 10 p.m. and 7 a.m. to be ten decibels louder than operations occurring during the daytime to account for increased annoyance when ambient noise levels are lower and residents are sleeping. The symbol for DNL is L_{dn} (International Civil Aviation Organization, 2008).

1.7 Assumptions

The dissertation must assert the following assumptions that are inherent to the study:

- All publicly data collected by Boeing were accurately reported by the airports and accurately recorded by Boeing
- Airport operators are concerned about the welfare of the communities they serve
- Airport operators are attentive to federal aviation regulations and other federal laws concerning noise pollution
- Airport noise mitigation policies target aircraft disturbing the community
- Noise pollution from aircraft is a concern to airport operators, local communities, and government

1.8 Limitations

The following limitations are inherent to this study:

- The current airport policy data were limited to the year 2011, the most recent collection period by Boeing
- The airports under observation were limited to the 132 Class B and Class C public commercial airports in the United States
- Noise complaint data were only collected from the 132 airports under observation for the year 2011
- All airport characteristic data and community data were examined for the year 2011 to be consistent with the Boeing airport database

1.9 Delimitations

The following delimitations are inherent to this study and may limit the scope of the research:

- The airport policies available for study were only in the United States and comparisons to international airport noise policies were not studied
- This study did not focus on the effectiveness of airport noise mitigation policies
- This study focused on noise policy implementation at airports and not on specific aircraft producing noise

1.10 Summary

This chapter has introduced the foundation of this dissertation. It has outlined the background and significance of the problem, and the purpose of this study. In addition, it has presented the assumptions, limitations, and delimitations providing the direction and constraints for which the research will be completed.

CHAPTER 2. REVIEW OF LITERATURE

This chapter provides a review of relevant literature and prior research related to a variety of subjects surrounding aviation noise. It includes a history of international and United States federal regulations as well as an overview of the technical aspects of monitoring aircraft noise production. It also includes a thorough discussion of theoretical perspectives that describe the political and institutional environment of aviation.

2.1 Organizational Structures Regulating Aircraft Noise

The International Civil Aviation Organization initially began discussing concerns over aircraft noise in the late 1960s and early 1970s and the United States adopted aircraft noise regulations in 1969 (Yeowart, 1972). Since then, noise concerns have received intense scrutiny at the international level, resulting in the first set of international protocols in 1971, known as Standards and Recommended Practices (SARPs), through the 16th Annex (Annex 16) to the Convention on International Civil Aviation of 1944 (International Civil Aviation Organization, n.d.). Expanding the scope of Annex 16 to incorporate the broad category of environmental protection, aircraft noise issues and standards became Volume I of Annex 16 in 1981 (International Civil Aviation Organization, n.d.). Currently, Annex 16 is in its sixth edition and there are six independent documents, including one circular, that provide guidance exclusively on aircraft noise issues (International Civil Aviation Organization, 2014). Volume I of Annex 16 establishes procedures for measuring aircraft noise certification standards (Claes, 2000). The most recent edition of Annex 16 was published in 2011 (International Civil Aviation Organization, 2014). There are five documents circulated by ICAO pertaining to noise SARPs as well. These include Doc 9501, Doc 9829, Doc 9888, Doc 9911, and Doc 9943. ICAO Circular 317 also pertains to noise. Document 9082, discusses the basis for charges and air navigation services and therefore identifies procedures for addressing charges based on noise emissions (International Civil Aviation Organization, 2012). These documents provide the most recent assessment from ICAO on the impact of noise globally and the procedures ICAO recommends to monitor and mitigate the harm it may cause to the surrounding environment.

The ICAO began its first discussions on creating standards concerning aviation noise in 1966 at the International Conference on the Reduction of Noise and Disturbance of Civil Aircraft (International Civil Aviation Organization, n.d.). In preparation for issuing SARPs, the Committee on Aircraft Noise (CAN) was formed to examine procedures involving the certification of aircraft based on noise standards; the CAN's recommendations resulted in the ICAO Council adoption of the initial *Annex 16- Aircraft Noise* in 1971 (International Aviation Civil Organization, n.d.). In 1972, the ICAO solidified its desire to regulate international standards at the United Nations Conference on the Human Environment (Miller, 1998). This focus on environmental problems as a whole expanded the scope on noise to include the broad impact of aviation on all environmental concerns. This resulted in the creation of the Committee on Aircraft Engine Emissions (CAEE) in addition to the CAN; these two committees were combined into the Committee on Aviation Environmental Protection (CAEP) in 1983, after Annex 16 was expanded into Volume I- Aircraft Noise and Volume II- Aircraft Engine Emissions (Claes, 2000). As of 2013, the CAEP consisted of 23 members and 15 observers (consisting of 5 additional non-member states and 10 organizations); a third volume to Annex 16 is expected to focus on $C0_2$ emission standards for aircraft (International Civil Aviation Organization, n.d.).

Volume I of Annex 16 consists of five parts, six appendices, and eight attachments outlining the SARPs adopted by ICAO. Part I consist of the definitions important to the understanding of the annex; Part 2 contains 13 chapters outlining the specific SARPs, with each chapter pertaining to a different aircraft category or type (International Civil Aviation Organization, 2011). There are noise standards pertaining to subsonic jet aircraft certified prior to October, 1977, subsonic jet and propeller aircraft between 1977 and 2006, subsonic jet and propeller aircraft after 2006, helicopter certifications based on weight classifications, aircraft certified for short takeoff and landing (STOL) specifications, supersonic aircraft, and tilt-rotor aircraft. Chapter 9 pertains to noise standards for ground operations and the operation of engines known as auxiliary power units (APUs) that supply power to aircraft systems, but that chapter is still under development (International Civil Aviation Organization, 2011).

Part III of Volume I, Annex 16 describes the procedures for taking noise measurements for the purposes of monitoring noise levels; however, currently there are no issued standards and only one current recommendation that refers to the procedures outlined in Appendix 5 of the annex (International Civil Aviation Organization, 2011). In the same manner, Part 4 of Annex 16 provide recommendations for determining noise contours around airports and refers to DOC 9911 as a guide (International Civil Aviation Organization, 2011).

Part 5 of Annex 16 for aircraft noise provides guidance on implementing a "balanced approach to noise management" that includes reducing noise by focusing on the source of the problem, managing land-use programs, operational procedures that focus on noise abatement, and aircraft operating restrictions. These reductions should be implemented in a way that is cost-effective as well (International Civil Aviation Organization, 2011, p. V-1). ICAO Doc 9829, Doc 8168, Doc 9184, and ICAO Annex 6, Part I, Chapter 4 provide additional details on implementing and maintaining a balanced approach (International Civil Aviation Organization, 2011). Annex 6, Part I details the aircraft operation SARPs for international commercial air transport regarding airplanes (International Civil Aviation Organization, 2010). Chapter 4 of Annex 6, Part I (2010) explains the SARPs for noise abatement procedures; however, only recommendations are made referring to DOC 8168 for further guidance and recommending that all aircraft of the same type should have the same noise abatement procedures at a particular airport. DOC 8168 describes procedures for air navigation services regarding aircraft operations (PANS-OPS) and chapter 7 discusses recommended noise abatement procedures (International Civil Aviation Organization, 2006). This chapter is cautious in providing explicit instructions stating, "Noise abatement procedures shall not be implemented except where a need for such has been determined" (International Civil Aviation Organization, 2006, p. 1-7-1-1). The document does not offer specifics about what should be included in a noise abatement procedure, but instead focuses on when a procedure should not be used; safety is the first priority and no procedure should exceed any normal flight parameter (e.g. the bank angle in a turn should not exceed 15 degrees). The procedure should also be able to be disregarded if at any time an unsafe situation is determined by a pilot or crewmember (International Civil Aviation Organization, 2006). ICAO Doc 9829, *Guidance on the Balanced Approach to Aircraft Noise Management* (2008) reiterated the concerns about noise abatement procedures, but also stated that noise abatement procedures should be addressed through the use of preferred runways, preferred departure and arrival routes, and specific takeoff and approach procedures. Three types of mitigation strategies are identified in DOC 9829 (2008) and include planning instruments, mitigating instrument, and financial instruments. These strategies can include zoning regulations that prevent residential and educational settings from locating close to an airport, land acquisition or noise barriers at and around airport property, and implementing taxes or charges associated with noise mitigation (International Civil Aviation Organization, 2008).

Noise mitigation strategies as identified by ICAO are typically issued more as recommendations than standards. One of the opening statements of Annex 16 stated about noise concerns, "*Whereas* the problem of aircraft noise is so serious in the vicinity of many of the world's airports that public reaction is mounting to a degree that finds cause for great concern and requires urgent solution" (International Civil Aviation Organization, 2011, p. xi). This initial resolution was adopted in 1968 and chapters 3, 4, and 5 of Annex 16 regarding aircraft noise are still under development with no indication of completion in the near future. The 9th session of the Committee on Aviation Environmental Protection (CAEP) made further suggestions to ICAO that included increasing the perceived noise level certification, and changes to aircraft noise standards. They also recommended standards for tilt-rotor aircraft (Dickson, 2013).

The United States, bound by international treaty as a signatory member of ICAO, is expected to comply with SARPS adopted by ICAO. The Federal Aviation Administration (FAA) regulations are very similar to international standards (Blackshaw, 2004) with differences existing largely in terminology. The chapters identifying aircraft characteristics and certification years under ICAO Annex 16 are referred to as stages (Blackshaw, 1992). Advisory Circular 150/5020-2 addresses the ICAO guidance for a balanced approach to noise management and states that airports should use the ICAO documents as guidance for developing proper procedures (Federal Aviation Administration, 2004). The FAA is aware of the ICAO recommendations and has taken steps to make airport operators aware of those recommendations through official documentation. However, FAA states,

> In preparing the balanced approach document, ICAO recognized that Member States have laws, existing arrangement, and policies that may govern managing noise problems at their airports. Therefore, any existing U.S. laws, regulation, policies, and obligations incurred under Federal agreements for surplus property as airport development grants supersede the *Guidance on the Balanced Approach to Aircraft Noise Management*. (Federal Aviation Administration, 2004, p. 1)

Since federal regulations are acknowledged to preempt ICAO protocol, this demonstrates the conflict that exists between ICAO SARPs and the abilities of some member States to comply with those procedures. Advisory Circular 91-86 is explained by its title, *Guidance on Carrying Noise Certification Documents on Board Aircraft Operating Outside of the United States*, and refers to ICAO Annex 16 Volume I (Federal Aviation Administration, 2010). It lists the methods that are appropriate, according to ICAO guidelines, in order to comply with United States law and ICAO standards (Federal Aviation Administration, 2010).

United States aircraft noise mitigation strategies also occur on a local airport level as airports choose to restrict aircraft from operating at certain times, or attempt to override federal regulations with their own restrictive policies (Blackshaw, 1992). The ability to regulate noise standards at a federal or international level is challenging and complex. The expected growth in the number of certificated aircraft and the increasing age of the aircraft currently used in commercial aviation present noise pollution challenges that take resources and changes in operational behaviors to overcome. Despite this, ICAO has made continual progress in addressing noise pollution and continues to address it as a serious problem for the future of aviation (International Civil Aviation Organization, 2011). Moreover, as required for ICAO member States, the FAA has followed the guidance of ICAO and adapts its regulations as ICAO establishes further practices. 14 CFR 36 section 105 cites Annex 16, Volume I and addresses the differences in terminology, but identifies that a Stage 4 aircraft will comply with SARPs published in Chapter 4 of Annex 16, Volume I (U.S. Government Publishing Office, 2015). The United States has been regulating noise at airports since the Aircraft Noise Abatement Act of 1968 and despite some differences with ICAO SARPs, issues formal guidance and policy based on those practices.

2.2 Aircraft Noise Measures

There are several different ways to measure aircraft noise depending on the reason for collecting data on noise levels. Title 14, Chapter 36, of the United States Code of Federal Regulations (14CFR36) describes the federal regulations for certifying aircraft noise compliance standards. (U.S. Government Publishing Office, 2015). Measuring noise involves measuring the sound waves in the form of energy that has an effect on a human (U.S. General Accounting Office 2000). The most basic unit of noise is the decibel (dB), which is a measure of sound pressure. One dB is equal to a sound pressure level and each unit increase is related to a logarithmic scale so that an increase from 1 dB to 2dB is an increase by a factor of 6 (Gesell, 1981). In general, the higher the decibels, the louder it will sound, and from 50 to 60 decibels the sound is doubled, and from 60 decibels to 70 decibels the sound is doubled again (U.S. General Accounting Office, 2000). According to Advisory Circular AC36-3H, the Federal Aviation Administration (FAA) requires the reporting of noise levels for certificated transport category aircraft and large turbojet aircraft to be reported in Effective Perceived Noise Levels in decibels (EPNdB), but most other aircraft are measured using A-weighted decibel (dBA) noise levels (Federal Aviation Administration, 2012a).

According to Yeowart (1972), The Port Authority of New York was the first to place decibel limits on aircraft flying into J.F. Kennedy Airport to 112 PNdB (Perceived Noise level, measured in decibels) after conducting an investigation on its own to determine an acceptable level. A Perceived Noise Decibel Level (PNdB) is a tool to give weighted meaning to the measure of sound, usually measured in decibels. It was developed because the noise spectrum for jet aircraft is different from that of a propeller aircraft and the human ear perceives two sounds at the same frequency (usually A-weight) decibel level (one from a jet and one from a propeller) to be different, with the jet sound perceived to be louder (Traux, 1999.). The A weight scale (dBA) is the most commonly used weighting scale because “it gives greater weight to frequencies that are heard by human beings and which might be found objectionable by the individual” (Gesell, 1981, p. V-9).

ICAO includes noise standards and recommended practices under Annex 16 of the Chicago Convention (the treaty that established ICAO and the foundations for international standards), including land-use planning, operational restrictions, noise abatement procedures, aircraft noise certification levels, etc.; these standards are aimed at reducing the negative effects of aircraft noise such as disrupting neighborhoods at night or long-term hearing damage (Girvin, 2009). Under the United States Code of Federal Regulations Title 14, Part 36: Noise Standards: Aircraft Type and Airworthiness Certification (14 CFR 36), the FAA places limitations on the maximum permitted noise level generated by aircraft (U.S. Government Publishing Office, 2015). 14 CFR 36 includes information on the parameter classifications (decibel level, weight, etc.) of the different stages of aircraft for aircraft certification purposes based on maximum loudness the particular aircraft produces with regards to engine and airframe noise.

ICAO Annex 16, Volume I (2011) defines several of the common noise measurement levels used by the FAA. The perceived noise level (PNL) measured in PNdB is defined as, “The perceived noise level at any instant of time” (p. APP 1-19). The effective perceived noise level (EPNL) measured in EPNdB is defined as, “The value of PNL adjusted for both the spectral irregularities and the duration of the noise” (p. APP 1-19). Section 4.1.1 of Appendix 1 in Annex 16, Volume I states, “The basic element in the noise certification criteria shall be the noise evaluation measure designated effective perceived noise level, EPNL, in units of EPNdB, which is a single number evaluator of the subjective effects of airplane noise on human beings" (p. APP 1-6). The measurements account for the level of noise as well as the frequency distribution and the time variation (International Civil Aviation Organization, 2011). To record the PNL of an aircraft, "most major airports place microphones on long poles at measured distances which record the noise of aircraft taking-off and landing" (Blackshaw, 1992, p. 230).

Another common measurement is the day-night average sound level (DNL) often used when determining airport noise contour maps and determining residential sound impacts. The United States Congress passed the Aviation Safety and Noise Abatement Act (ANSAA) in 1980 mandated a single system for airports to measure noise, identify individuals exposed to aircraft noise, and identify land use (e.g., lakes, open fields, and freeways) suitable for noise exposure (Blackshaw, 1992). The ASNAA also established a federal fund that allowed airport operators to submit noise exposure maps and receive partial funding to develop the airport in ways that reduced the noise imprint (Blackshaw, 1992). This gave airport operators more incentive to track noise paths and noise levels of aircraft arriving and departing. The FAA accommodated airport noise level monitoring through Advisory Circular 36-3 (currently 36-3H) by converting the ICAO mandated EPNL calculations to estimated dBA weighted levels for each certificated aircraft (Federal Aviation Administration, 2012a; Federal Aviation Administration, 2012b).

While there are mathematical formulas to determine an increase or decrease in noise, the overall effect it has on an individual human is subjective (U.S. General Accounting Office, 2000). The effect aircraft noise has on individuals in a community results in varying degrees of harm to individuals. Noise interferes with activities such as sleeping, thinking, and relaxing (U.S. General Accounting Office, 2000). The Santa Monica Airport Association attempted to sue the City of Santa Monica to restrict the types of aircraft that would be allowed and perceived the newer business jets as a threat to the quietness of the community (Santa Monica Airport Association, 1979). Around airport communities, the Maximum Sound Level method and the Sound Exposure Level method are two measures commonly used to monitor noise from a single takeoff or landing (U.S. General Accounting Office, 2000). The Maximum Sound Level method identifies the peak decibel (dBA) produced from a takeoff or landing event but does not consider the duration or total sound energy produced. The Sound Exposure Level method considers the duration of the sound as well as the intensity, and therefore two measures of the same intensity could have different noise levels depending on the duration of exposure to the sound (U.S. General Accounting Office, 2000). It is possible noise complaints may be an indicator of the impact of noise on a community. However, attempting to evaluate the impact of noise and the associated disturbances is challenging because of the potential bias individuals have when disturbed by noise. It is also hard to pinpoint if the noise heard was actually an aircraft, or other noise that was associated as an aircraft (Collette, 2011). Despite this, communities have established complaint calling stations at most airports and citizens are encouraged to use it when they are distracted by an aircraft noise (Collette, 2011).

The ability to measure noise levels has an effect on the operation of particular aircraft type in the United States. As older aircraft are phased out of service because they do not meet current FAA noise requirements as established in 14 CFR Part 36, manufacturers have to find new technology to make aircraft quieter, and companies have to replace their old fleets with newer and quieter aircraft (U.S. Government Publishing Office, 2015). Girvin (2009) notes, "takeoff noise from a current-production Boeing 737-300 sounds less than one-third that of an equivalent 1965-technology aircraft" (p. 14). In addition to replacing aircraft, several procedures can be utilized to reduce the noise impact, ranging from eliminating certain flight patterns over congested areas to curfews at airports that restrict arrivals and departures (Gesell, 1981). Ronald Reagan Washington National Airport places a curfew on all aircraft from 9:59 p.m. until 7:00 a.m. except in the case of emergency, with a fine associated with a violation (Boeing, 2011). Noise abatement procedures for takeoff also present problems for aircraft as each airport has different geographical considerations that make departures different and complicated depending upon the procedure used and the type of aircraft using the procedure (Aurbach, 1977). Spence, Vath, Kwak, and Johnson (2015) evaluated the application of noise monitoring systems at San Francisco International Airport (SFO) and determined that decibel thresholds at the monitoring stations are more likely to be violated by larger aircraft, especially international aircraft crossing the Pacific Ocean. However, for U.S. domestic airlines, indications have shown that the numbers of violations are on a downward trend (Spence et al, 2015).

Noise measuring methods make it easier to track how much noise is affecting a community and where that noise is being distributed. It also allows manufacturers and regulators to closely monitor the output of noise for each aircraft. This led to an increase in standards and policies at local, federal, and international levels. As monitoring equipment becomes standardized around the world, international airports are able to monitor noise paths of all aircraft as well. Despite continuous monitoring and improvements in technology, noise is affecting an increasing number of airports every year as the number of passengers and aircraft increase (Netjasov, 2012). Measuring techniques have implications that affect the industry for manufacturers, pilots, and government.

2.3 Noise Limitations on Manufactured Aircraft

Advisory Circular AC36-1H provides data on aircraft noise levels and states the respective noise qualification stage for each different aircraft type, model, and possible manufacturer configuration (e.g. GE engines or Rolls-Royce Engines) (Federal Aviation Administration, 2012a; Federal Aviation Administration, 2012b; Federal Aviation Administration, 2013). Under Federal Aviation Administration (FAA) regulations, a civil jet aircraft can receive a noise rating as Stage 1, Stage 2, Stage 3, or Stage 4. Stage 1 ratings signify aircraft in the loudest group and Stage 4 signify the quietest group. Aircraft with a maximum takeoff weight (MTOW) exceeding 75,000 pounds in the contiguous United States must meet Stage 3 or Stage 4 requirements. Aircraft at or below 75,000 MTOW must meet Stage 2, 3, or 4 requirements. In order to operate on or after January 1, 2016, the FAA is requiring all civil jet aircraft, regardless of MTOW, to meet Stage 3 or Stage 4 requirements (Federal Aviation Administration, 2014). Until 2016, a jet aircraft lighter than 75,000 MTOW may be louder than a heavier aircraft and still receive operational certification.

The FAA regulated the stage classification in 1990 through the Airport Noise and Capacity Act (ANCA) that changed the scope of commercial aviation aircraft in the United States (Lawrence, 2004). The ANCA removed the loudest, Stage 1 aircraft from commercial service and mandated that no more aircraft would receive Stage 2 certification, leaving only Stage 3 aircraft as the new generation (Lawrence, 2004). The stage certifications specified in 14 CFR part 36 contain noise standards based on aircraft type for airworthiness certification in the United States (U.S. Government Publishing Office, 2015). Appendix B to 14 CFR part 36 (2015) gives the specifications for each category and are as follows:

Stage 1: Noise limits of Stage 1 aircraft are greater than any limit specified in Stage 2 or above.

Stage 2: For a flyover and regardless of the number of engines, with a maximum takeoff weight (MTOW) of 600,000 pounds or more, the maximum EPNL is 106 EPNdB and then a reduction of 5 EPNdB for each halving of the 600,000-pound limit (aircraft having 300,000 pounds MTOW are restricted to a maximum 101 EPNdB). Any aircraft weighing 75,000 pounds MTOW or less is restricted to 93 EPNdB during a flyover.

For lateral and approach sound limits an aircraft of 600,000 pounds or more is limited to 108 EPNdB with each halving of the 600,000-pound limit requiring a reduction of 2 EPNdB. Any aircraft weighing 75,000 pounds or less MTOW is limited to 102 EPNdB.

Stage 3: During a flyover, for an aircraft with more than 3 engines and a MTOW of 850,000 pounds or more, the maximum EPNdL is 106 EPNdB with each halving of the 850,000-pound limit requiring a reduction of 4 EPNdB. A maximum EPNL of 89 is allowed for an aircraft with 44,673 pounds or less. If an aircraft has 3 engines and a maximum MTOW of 850,000 pounds or more, the maximum EPNL is 104 EPNdB with each halving of that MTOW requiring a reduction of 4 EPNdB. An aircraft weighing 63,177 pounds or less MTOW is limited to 89 EPNdB. An aircraft with fewer than 3 engines and a MTOW of 850,000 pounds or more has a maximum EPNdL of 101 EPNdB with each halving of the 850,000-pound limit requiring a reduction of 4 EPNdB. A maximum EPNL of 89 is allowed for an aircraft with 106,250 pounds or less.

For lateral noise limits, regardless of the number of engines, an aircraft with a MTOW of 882,000 pounds or more is limited to 103 EPNdB with each halving of the maximum weight requires a reduction of 2.56 EPNdB. An aircraft with a MTOW of 77,200 pounds is limited to a maximum EPNL of 94 EPNdB.

For approach noise limits, regardless of the number of engines, an aircraft with a MTOW of 617,300 pounds or more is limited to 105 EPNdB with each halving of the maximum weight requires a reduction of 2.33 EPNdB. An aircraft with a MTOW of 77,200 pounds is limited to a maximum EPNL of 98 EPNdB.

Stage 4: For all requirements of stage 4 aircraft the ICAO Annex 16 standards for chapter 4 apply and demonstrate the most current technological capabilities that is determined to be practical and reasonable.

Currently the FAA is in the process of establishing procedures to create Stage 5 noise limits that would reduce maximum noise production even more. These rules are expected to be implemented between 2017 and 2020 (Federal Aviation Administration, 2013).

14 CFR Part 36 became a part of the Code of Federal Regulations (CFR) on December 1, 1969 and was targeted toward newly-manufactured aircraft in response to

the expansion of jet aircraft (Federal Aviation Administration, 2009). In 1977, the FAA established the standards for Stage 1, Stage 2, and Stage 3 certifications and implemented the strictest requirements for manufacturers seeking airworthiness compliance for Stage 3 certification for aircraft manufactured after November, 1975 (Federal Aviation Administration, 2009). Beginning in 1985, the FAA began to phase out the certification of Stage 1 aircraft (Federal Aviation Administration, 2009). In 1999, Congress limited aircraft certification to Stage 3 noise requirements for aircraft over 75,000 MTOW; however, some aircraft have continued to receive exemption from the FAA (Federal Aviation Administration, 2013).

When the tests are performed for certification, they are accomplished so that the aircraft intentionally is in a configuration that produces the most noise, but typical (U.S. Government Publishing Office, 2015). Flyover, take-off, and approach tests are completed with specific parameters that are typical for a particular aircraft. For the flyover test, power is at full takeoff power, or the highest power setting approved in the flight manual (U.S. Government Publishing Office, 2015).

There are very specific tolerances and it is important to note that most general aviation aircraft are small propeller aircraft and are not subject to the Stage limitations specified in 14 CFR Part 36. Small commuter aircraft driven by a propeller are not subject to Stage requirements either (Federal Aviation Administration, 2009). However, these aircraft are still subject to noise certification standards that are specified in 14 CFR Part 36 subpart F. Small propeller aircraft are referred to as nonstage aircraft and must follow the procedures described in Appendix F and Appendix G for noise certification (Federal Aviation Administration, 2009). Under Appendix F or Appendix G the loudest aircraft to receive certification is 88 dBA for aircraft up to 19,000 pounds and this is for multi-engine aircraft weighing greater than 1,320 pounds or single engine aircraft weighing greater than 1,320 pounds MTOW and applied for certification prior to 2006. For new aircraft seeking certification after February, 2006, noise levels are restricted to 70 dBA for aircraft less than 1,257 pounds and a maximum of 85 dBA for single engine aircraft increasing at 9.83 dBA per doubling of weigh from 1,320 pounds up to a maximum of 19,000 pounds MTOW (U.S. Government Publishing Office, 2015). Because the small propeller aircraft are not subject to the Stage certifications, the unit of measurement is slightly different. However, the noise issues of small propeller aircraft are just as important as the larger transport commercial aircraft subject to Stage certification requirements as Chief Judge Hill (1979) noted *in Santa Monica Airport Association v. City of Santa Monica*, in reference to newer business executive jets,

> …the quality of the noise produced by modern type fan-jets and its alleged tendency to irritate and annoy, there is absolutely no difference between the noise of such jets and the noise emitted by the louder fixed-wing propeller aircraft which are allowed to use the airport. (p. 944).

The Santa Monica Airport Association attempted to ban jets from the airport because of the noise burden they exerted, but the evidence supported that new business jets were making similar noise to larger propeller aircraft.

The noise stages for aircraft certification have continued to become more stringent over time and older aircraft are continuously being phased out. Despite this, Part 36, Section 5 states, "...the noise levels in this part have been determined to be as low as is economically reasonable, technologically practicable, and appropriate to the type of aircraft to which they apply" (U.S. Government Publishing Office, 2015). This suggests that as technology improves and becomes financially feasible to promote even quieter aircraft, the FAA will continue to monitor and update the regulations as appropriate while maintaining the necessary safety standards. The section continues, however, "No determination is made, under this part, that these noise levels are or should be acceptable or unacceptable for operation at, into, or out of any airport (U.S. Government Publishing Office, 2015). The FAA will not make regulations that are impossible to comply with regarding aviation noise limitations. The purpose of the noise limitations reflects the technological advancements that manufacturers are capable of making; while noise limitations and stage requirements improve airport and community health, the regulatory section does not make inferences about the impact on the environment. Through the cooperation and coordination of the FAA, Congress, and ICAO noise limitations will continue to become more stringent, continuously making aviation quieter around airports as long as it is feasible and safe.

2.4 Institutional Frameworks for Aircraft Noise Mitigation

The aviation industry is a complex web of institutions and organizations that add to the challenge of finding policy solutions for issues like aircraft noise pollution. Three solutions to reducing the environmental impact of aviation could be in the form of reducing the number of aircraft operations, changing the aircraft types being used to less polluting aircraft, or changing the regulations under which aircraft operate (Clarke, 2003). They are also "laboratories for new strategies of both technological and social control" (Salter, 2008a, p. xi). International airports operate large multi-dimensional operations affecting people and the environment. The local, state, and federal governments are institutions built into the design of airport operation and policy. The Federal Aviation Administration (FAA) regulates the aviation industry in the United States and 14 CFR Part 36 establishes the federal regulations concerning aviation noise and maximum noise tolerances allowed for certification (Aurbach, 1977).

The airports also house businesses interested in making a profit. The dichotomy between public and public enterprise creates tension over economic practices and associated costs with implementing new strategies (Salter, 2008a). International governmental organizations (IGOs) as well as non-governmental organizations (NGOs) also play a foundational role in aviation policy. The International Civil Aviation Organization (ICAO), formed from the Treaty of Chicago in 1944, is a specialized agency of the United Nations (UN) that oversees international aviation safety practices and issues standards and recommended practices to the signatory member-states (Salter, 2008b). The International Air Transport Association (IATA) and Airports Council International (ACI) are established organizations that shape aviation policy and airport officials interact with these organizations on a continual basis (Salter, 2008b).

Finally, the residents in the local community surrounding an airport play a role that can impact airport policy, and airport noise reduction strategies. A particular method U.S. communities use to find a remedy to the disturbance from aircraft noise is through the use of the courts. Airport noise disturbances are not a recent occurrence; in 1977, airport officials paid more than $25,000,000 in damages as a result of damage on property due to aircraft noise (Aurbach, 1977).

Annex 16, Volume I is the ICAO document that provides guidance on the issues surrounding aircraft noise (International Civil Aviation Organization, 2011). The Annex, however, provides more recommendations than standards and states that sovereignty of the member states is important in determining the value of the standard. If member state regulation exceeds or diverges from the ICAO protocol the member state regulation does not necessarily have to change (International Civil Aviation Organization, 2011).

Community activism is a factor that shapes the way noise policy is adopted in and around airport communities. By 2011, Seattle-Tacoma International Airport in the Seattle, Washington area had spent over $500 million on mitigation programs that included land acquisition and insulation (Boeing, 2011). If the community had not voiced their concerns or actively sought aid for a community problem, then the money would not have been spent. Studies have shown that as the noise level increases in the community the annoyance it causes on a community also increases and the increase in annoyance helped the FAA establish the 65 dB DNL determination for insulation funding inside the contour around an airport (Schultz, 1978; Collette, 2011). The FAA uses studies completed by airports to provide funding for noise mitigation strategies with Part 150 of the Federal Aviation Regulations, (FARs) and refers to these studies as Part 150 studies (Collette, 2011). In addition to Part 150 studies, airports can also conduct FAR 161 studies as well. Part 161 studies are for "*Notice and Approval of Airport Noise and Access Restrictions*" and Los Angeles World Airports (LAX) is currently in the process of completing one in order to reduce the number of operations to the east (i.e. in the direction of the city) between 12:00 and 6:30 a.m. (Los Angeles World Airports, 2016).

Institutional frameworks like historical institutionalism can aid researchers in discovering the role that organizations and societal norms have in shaping public policies like airport noise mitigation strategies. As Falleti and Lynch (2008) noted, "Social processes are rarely instantaneous" (p.2). This means that policies involving societal implications do not occur without a prior sequence of events facilitating the creation of a particular policy. It is important to identify the beginning of the sequence through historical analysis and process tracing (Falleti & Lynch, 2008). In a historical analysis, the beginning part of a sequence can be referred to as a critical antecedent, indicating that an important event triggered a particular path or sequence that led to the resulting social implication (Slater & Simmons, 2008). Identifying the critical antecedent may be challenging; Slater and Simmons (2008) state, "No historical argument goes back forever, so political scientists inevitably have to choose where to truncate their temporal chain" (p. 7). A historical institutionalist perspective will help guide the analysis of the current status of noise mitigation strategies by focusing on the historical context of noise mitigation policies in the United States. An understanding of where noise policy began and how it evolved at the various levels of government will allow for better understanding of what caused divergence in noise mitigation policies at the local airport levels and why the federal government has not established more detailed noise mitigation regulations. Marshall (2014) and Rabe and Borick (2012) examined public policy in the United States and used an understanding of historical context to help draw conclusions. They state, "Policy ideas generated by the discipline of economics often face great difficulty when efforts are made to translate them into actual policy through political institutions" (Rabe and Borick, 2012, p.358). Noise pollution and noise mitigation strategies have evolved through a historical context as technology developed and political institutions were, and still are, forced to adapt to a rapidly changing industry.

The FAA, a bureaucratic government organization, is not immune to the political realm as the administrator is appointed by the President of the United States and reports to the Secretary of Transportation, a cabinet level position in the United States Government (Cornell University Law School, n.d.). The context in which noise mitigation policies have evolved at the federal level is important for understanding how noise mitigation policies have been adopted around the United States at the local airport level and to the extent that the policies diverge from each other at different airports. Whenever a noise policy is implemented, there are a variety of interested parties including the local airports, local airport communities, and the aircraft operators that must contend with the new policies whether it be reallocation of land through zoning laws, easements purchased for development, or charges in the form of taxes or charges for use of the airport (Gesell, 1981).

Bureaucratic offices (e.g. the FAA) often respond to congressional committees and interest groups, and this combination is often referred to as an iron triangle (Kingdon, 2011). The iron triangle means that outside groups perceive these organizations to be unreachable, and even the President or other government elites have very little control over the combination. When shaping aviation noise policy, constituents represented by a person on the congressional committee could end up receiving favorable policy outcomes whereas those who do not have direct personal representation may not receive the same outcomes (Kingdon, 2011). Also, interest groups (e.g. IATA, Airlines for America, National Business Aircraft Association) have a reason for promoting their values on issues and protecting the industry status as it is. As Kingdon (2011) states, “the lower the partisanship, ideological cast, and campaign visibility of the issues in a policy domain, the greater the importance of interest groups” (p. 47). Noise abatement issues receive concern from groups that are most directly affected; however, the noise is contained to a relatively isolated area and the area of the threshold of concern is getting smaller every year (Collette, 2011).

The interactions of relevant institutions and organizations are important for understanding the noise mitigation policies at airports. The formal institutions that regulate policy include ICAO, the FAA, other government agencies, and the airports that implement the policies. These formal institutions attempt to mitigate a problem through rules and regulations, but also consider the needs of their operational environment. Informal institutions, such as the underlying norms and values common in a community, and informal organizations that organize around ideas also influence the policy making process. A community with open space may react differently to airport noise than a densely populated environment with an airport near the urban center. Community activism contributes to the policy making process through formal and informal processes as well. Community organizations may attempt to contact congressional leaders for specific policy options, or may choose to force policy through numbers. Noise complaints may be an indicator of noise disturbance in a community. The evolution in formal policy through regulation over time also is an indicator of the importance of the issue. Evaluating how policies have changed, and the number of times new rules are implemented is important for understanding the current status of noise abatement strategy.

2.5 Concerns about Aircraft Noise Impacting Health

As more research around airports is being conducted, the concern for noise pollution on communities is increasing. The effects extend beyond the distraction and disruption of activities it can cause. Health effects attributed to aircraft noise are continuously being evaluated and research shows that disruptive noise levels can affect humans negatively. A 2002 study published in the *Journal of Epidemiology and Community Health* examined the effects of test scores of students who attend school in the vicinity of the London Heathrow Airport. The study involved approximately 11,000 students from 123 schools in the areas surrounding Heathrow Airport. Researchers determined that "…chronic exposure to aircraft noise was significantly related to poorer reading performance and was not associated with other English performance outcomes, spelling, writing, and hand writing" (Haines et al., 2002, p. 143). The study also found that students exposed to chronic aircraft noise performed poorer on standardized mathematic tests. The researchers concluded that chronic noise exposure had an impact on mathematics and reading performance, but that socioeconomic factors confounded the results (Haines et al., 2002).

In addition to academic performance, aircraft noise also affected the physical health of those exposed to noise. In July 2010, a review of literature pertaining to health effects of aircraft noise was created through a Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) project (Swift, 2010). This project concluded that serious adverse health consequences have been linked to aircraft noise, particularly at night. Two major health issues, hypertension and heart disease, were cited in several studies as potential health risks attributed to lack of sleep resulting from aircraft noise.

Lack of sleep due to aircraft noise also has been shown to contribute to obesity and diabetes. Although many of these health issues can be attributed to noise in general, noise produced by aircraft is a contributing source (Swift, 2010).

Noise pollution is harmful to communities. Noise affects people and animals by filling what would otherwise be a quiet environment with unnatural, manmade noise at high intensity levels. Pepper, Nascarella, and Kendall (2003) stated, “The two most important elements of noise exposure in wildlife are the proximity to the airport and the frequency of overflight” (p. 425). Animals rely heavily on their hearing to obtain food, evade predators, and reproduce. Loud aircraft noise may change their behavior patterns, potentially causing a lifelong change in behavior. Studies have shown that animals exposed to excessive noise typically exhibit a fright response, resulting in the animal attempting to escape the source of the noise. The habitat where the animal resides may affect its response to aircraft noise (Pepper et al., 2003). Animals may respond more aggressively around airports that are surrounded by large open fields, compared to airports that are located in busy urban environments. This is a result of the increased noise in open environments due to the lack of natural sound barriers in forests or urban areas (Pepper et al., 2003). Many airports have implemented environmental components to their noise reduction programs in an attempt to mitigate effects on natural animal habitats. It is important to understand the impact on animals because airports own a lot of undeveloped property that is home to many species of animals, including ground-based deer and foxes as well as many varieties of birds. If these animals become confused or aggressive they may wander onto airport surfaces that impede aircraft or endanger ground personnel (Pepper et al., 2003).

Whether the noise is just an unwanted disturbance, creates a noticeable injury such as increased fatigue, or hypertension from increased stress, or decreases performance in work or school, creating remedies to these problems have been very difficult. Grassroots movements can bring about political change through community engagement and activism. Clark et al. (2010) found that community activism affected the policy outcomes in statewide legislation. The authors stated, the "…wisdom and unique experience of the participants in a coalition effort produce richer information and more relevant decisions" (p. 904). Most airport communities have community organizations that are attempting to reduce the noise imprints around airports. The San Francisco community has two active local community groups- Sky Posse Palo Alto and UPROAR- not content with the intergovernmental agency that is dedicated to reducing aircraft noise (UPROAR, n.d.). The New York City Metropolitan area, however, does not have a municipality organization focused on noise mitigation and there are six active organizations. These are the Quiet Skies Over Nassau, New Jersey Coalition Against Aircraft Noise (NJCAAN), Prospect Park Quiet Skies, Quiet over Garden City, Quiet Skies Coalition and the East Hampton Quiet Skies Coalition. These groups all have one centralized location with the exception of the East Hampton Quiet Skies Coalition online at quietskies.net (Quietskies, n.d.). The community organizations are active in voicing their concerns when they feel the municipality organizations are not serving the best interest of the communities.

While airport officials attempt to reduce aircraft noise through the use of specialized approach and departure procedures, airport quota restrictions, etc., commercial and residential properties are still being constructed near airport premises'.

According to a PARTNER study on land use management and airport controls, the San José International Airport, located just south of San Francisco, California has experienced an increase in noise complaints as a result of newer residential properties being constructed near the airport property (Li & Eiff, 2008). One area known as Communications Hill (a residential housing area seven miles south of the airport) is expected to house 10,000 residential units upon completion of construction. Airport officials are already receiving an increase in noise complaints from residents in this area, and the construction has yet to finish. Li and Eiff (2008) found that real estate developers and their clients were not engaged in discussion about the proximity of prospective homes in relation to airport paths.

Science is an important, but not the only, means for discussing and implementing policy options. Foster (1999) makes this clear when he states, "the crisis of the earth is not a crisis of *nature* but a crisis of *society*" (p. 12). The values humans place on their livelihoods, the market economy, and profit will continue to create burdens for the environment and for all humans and animals who inhabit the earth. Science can work in tandem with societal values to produce viable outcomes that result in both the preservation and conservation of the environment. Environmental issues affect people in different ways based on how they interact with the environment. Someone with acute hearing loss from aircraft noise flying over the neighborhood is more likely to be sensitive to noise pollution issues around airports than an airline CEO who is concerned about providing a service for the expanding traveling public. Science may be able to sufficiently substantiate both concerns and need to be considered when determining how to address policy concerns in the future.

McAdam (1999) established political process theory (PPT) as a way of understanding social mobilization. While prior researchers focused on resource mobilization (elites providing resources to marginalized groups), PPT incorporates the power dynamic and community emotions for understanding mobilization of a group. This theory could help explain community organization around airport noise and the creation of community groups specifically focused on combating airport noise.

Another difficulty in establishing acceptable remedies to injury for noise pollution is that property rights are not clearly defined. Falzone (1999) describes the system as a "…complicated web of federal, state, and local legislative and judicial decisions" (p. 800). Damage from aircraft noise is difficult to assess because it is challenging to determine who has responsibility. Noise travels beyond airport boundaries to other private and public properties. Also, when an aircraft is in the air, questions arise as to who is responsible for the air from which the noise originates. Ownership of property can be divided into 4 categories: state property, private property, common property, and non-property (Cole, 2002, p.9). Non-property is something (usually land) that lacks any ownership. In non-property scenarios there are no restrictions on who has access to the resource and no restrictions on how that resource can be used. Cole (2002) differentiates common property from non-property by describing common property as that which a group of people have ownership rights and the ability to exclude outsiders from use.

As populations grow, demand for air services increase and larger aircraft are generally required. Some of the largest cities in the world often require airports that operate 24 hours a day in order to meet travel demands. In terms of quiet air as a resource, much like a quiet environment, it is being depleted and it is affecting the people living near these large airports. There is a correlation between the annoyance people have with aircraft noise and the level of noise being produced by the aircraft (Collette, 2011). The people in the vicinity of the airport as it departs or arrives lose the ability to live residential and business environments without aircraft noise. The airlines feel the pressure of the consumer to provide the service over the possible harm of disrupting somebody's sleeping pattern. From the airlines' point of view, the consequences of not providing the service are much greater than any possible consequence (i.e., a complaint from a non-customer) from flying over an area at an inconvenient time for someone on the ground.

2.6 Principal Economic Approaches to Noise Regulation

One possible solution for allowing aircraft to fly over a residence at any hour is to privatize the air (i.e. allow for free-market transactions between individuals where state intervention is absent). Anderson and Leal (2001) believe this solution is very important because it is most agreeable with human nature and allows for a free exchange of quid pro quo. They state, "Like it or not, individuals will undertake more of an activity if the benefits of that activity are increased or if the costs are reduced" (Anderson & Leal, 2001, p. 66). In the case of airlines providing a service to a destination, as more people convey the desire to travel, more airlines will provide that service both by increasing the number of flights and by increasing the size of aircraft. If, however, there was a cost for traversing the property of a resident near the airport who was particularly disturbed by the noise then airlines may be forced to consider other options for arriving at a destination.

Anderson and Leal (2001) address the issue of clean air which is similar to noise pollution. Air is a difficult item to privatize because the boundaries are not strict. However, the government could regulate those precise boundaries. In the case of being able to own air, the government could determine that when property is purchased it includes all of the air up to 10,000 feet. Aircraft have to descend eventually and once they reach the threshold of 10,000 feet then they would be required to negotiate with the owners of the properties that are crossed and pay them for the disturbance. Anderson and Leal (2001) believe that free-market environmentalism simply puts a cost on every transaction because ownership rights are clearly defined. If an action is necessary, then a transaction will occur.

While the free-market approach to mitigating noise pollution seems theoretically possible, there are many immediate challenges that would severely limit its ability to accomplish anything, even if the ownership boundaries are explicitly defined. One of the challenges associated with free market transactions would be that every individual who owns property would have to monitor the boundaries of the property to determine if an aircraft trespassed without the appropriate compensation as well.

A possible solution to individual property problems is common property, or property privately owned by a community of people. Cole (2002) described how several communities around the world have used common property practices to avoid the tragedy of the commons. One example he described occurred in Turkey where the right to fish certain fisheries was limited to a particular village or neighborhood. The mayor of each village received a list of people allowed to partake in the commons (Cole, 2002, p. 119-120). Citizens of a community could organize similarly and claim ownership of the right to peaceful air as a community. Most international airports are owned by the city; charging airlines a fee for the noise they produce would only be an extension of the common property ownership. The community could then agree upon how much noise is too much and create agreeable levels. Fees collected could then be put to use for other community projects that benefit those in the community, or funds could be redistributed to members of the commons as reimbursement. The issue of monitoring noise levels from aircraft entering defined property limits still would be required. These monitoring systems could be more of a burden to some communities more so than others, but many cities are beginning to set up monitors already. Defining the boundaries of the property remains a challenge in this model, and continuous monitoring would be required. As the policies at San Francisco International Airport demonstrate, the airspace over a community can be a considered common property belonging to the resident in the City of San Francisco (San Francisco Community Roundtable, 2010). They chose to allow aircraft to enter their airspace, only under certain noise conditions. If airlines violate that noise condition, then a fine is assessed. Noise monitors are situated throughout the community to assess compliance. According to the *Rules and Regulations of the San Francisco International Airport* (2009), the first exceedance of a noise level as recorded by a monitoring station in a twelve-month period results in a letter of admonishment from the Airport Director. The second violation in the same twelve-month period results in a fine of 1,000 USD. A third violation in the same twelve-month period results in a 2,000 USD fine and each additional violation thereafter results in a 3,000 USD per occurrence.

Private property rights would be a fair approach to limiting noise pollution in a community by creating a system of Individual ownership, to the extent that they would have direct control over letting an aircraft fly directly over their property. If the community gets together and creates a common property to air ownership, it could provide a unified voice to a much larger area, but would reduce the ability of people more sensitive to noise to be compensated more than others. One of the most difficult problems would be defining the boundaries of ownership of the air. Determining if all air within an individual's property extends up to a specific height, or if a common property extends to city or town borders as well as determining height are significant challenges to identifying property rights for air.

The opposite approach to exclusively owned private property is entirely state-owned property. However, making the air owned by the state for the purpose of mitigating noise presents its own benefits and challenges. Foster (1999) is an advocate for state owned property to mitigate environmental problems. Foster's argument is that changed needs to be made on a societal level, and a central authority does a much better job at understanding environmental problems than the individual citizens, susceptible to the whims of corporate interests and greed. Foster (1999) states, "Government will have to play a more active role in environmental regulation, corporations will have to reform to become more environmentally responsible, and a 'green' industrial strategy will have to devised to ensure that development remains sustainable" (p. 130).

Because of the interest in a safe mode of travel for the public the aviation industry in regulated extensively from the federal government through the Federal Aviation Regulations (FARs) and controls operations of aircraft on the ground and in the air (SFO Community Roundtable, 2010). The Federal Aviation regulates aircraft noise through 14 CFR Part 36 (U.S. Government Publishing Office, 2015). Through regulation the government could feasibly dictate that any aircraft flying through the air at any altitude is on federal property and therefore under federal control, claiming ownership of the air. The federal government would then be able to regulate specific noise levels aircraft are allowed around communities, and specific times when aircraft can produce noise.

There are several problems to state ownership however, especially something that is as fluid as air. Cole (2002) discusses several problems with state ownership. One specific problem is that bureaucrats do not efficiently regulate what they control because they are tasked with finding solutions to issues in which they do not have any personal investment. Because of this they fail to seek the optimal solutions and do not understand all of the consequences of a particular decision. Cole states, “Because public resource managers do not personally own the resources under their control, they do not suffer personal financial losses if they make poor management decisions” (Cole, 2002, p. 39). Cole also states that command and control regulation, where the state creates a specific requirement that needs to be met in attempt to solve a problem, is the most common form of state regulation (Cole, 2009). Either the FAA or a special institution created for noise mitigation around airport communities would potentially use command and control style regulation to make policies. They could specifically regulate the decibel level for an engine, the hours during which an aircraft can operate at a facility, the altitudes and specific flight patterns for departures and arrivals, along with the many other factors associated with noise creation and pollution. This would require an even larger bureaucracy to understand how noise affects every community. The bureaucrats then have to decide if a “one-size fits all” policy is sufficient, or if different communities need different policies. Terrain, population size, airport location, and city infrastructure are different in different depending on the location of the noise and affect how noise from a particular aircraft actually impacts a community. Also, if the state chooses to own all air, the institutions would have to decide if all pollution is considered the same, or if each situation is different.

In contrast to command and control approaches, state ownership of air is another possible way to attempt to mitigate noise pollution from aircraft. However, several issues would arise in trying to find a best-fit scenario for all communities. An issue that arises when government bureaucrats determine regulations to control locally occurring problems is that they “are not personally invested in the resources under their control” (Cole, 2002, p. 88). The bureaucrats may not fully understand the consequences of their actions, or realize different scenarios are required in different places. Industry would be stifled in innovation as they are forced to comply with specific standards.

There are merits and challenges to both private ownership and state ownership. For the purpose of noise mitigation, a mixed approach combining some elements of both systems may be best. Cole (2002) describes the mixed approach when states, “Examples of this type of partial privatization include the issuance of pollution permits (whether transferable or not) and the granting of private concession to manage resources on public lands” (p.45). Burtraw and Sekar (2013) call this design a “polluter pays” principle (p. 1). This system allows for the state to take control of the ownership and make necessary regulations limiting the total amount of pollution. It also allows for a version of free market environmentalism through the market distribution of allowances. Industries, the ones responsible for creating pollution, are the ones that pay for polluting. It is good that those that do the polluting pay for the pollution, but as Burtraw and Sekar (2013) point out, “The fundamental question of to whom this payment should accrue, we argue hinges on whether one views the atmosphere resource as belonging to the state or to individuals (held in common)” (p. 3). Once there are funds available, a question arises as to whether the funds should be owned by the state, or dispersed to the people affected by that pollution.

To mitigate noise pollution from airlines, this type of system may be positive solution. The government can use academia and industry to understand how noise affects communities and establish critical areas where noise may be having detrimental effects on people and animals. If there are schools near busy airports, students may have lower grades because of the distraction from continuous jet noise. Once a decibel limit is set airlines can be given a certain amount of noise credits to pollute communities with a maximum amount of noise. If airlines operate older aircraft or a lot of aircraft at times when people are especially sensitive to noise, such as nighttime, they will have to purchase more noise credits to be compliant. The program can be administered regionally like the Regional Greenhouse Gas Initiative or the California cap and trade system, where several cities or states participate on a smaller program (with several throughout the country) that is one segment of a larger program (Burtraw & Sekar, 2013). The program can have a federal oversight to regulate prices and maximum noise levels, but the regional communities will better know how to adapt their procedures for local airports. Because factors like wind and terrain make noise patterns different across the country, local understanding of these patterns is necessary.

Barnes and Breslow (2003) suggest that an ideal solution is to create a trust fund that pays everyone in the community equally. This is one option to help those who are injured most by providing a direct monetary subsidy. Property values tend to be lower around airports because of the noise impact and therefore assisting those could redistribute income progressively. The lower income earners would receive more compensation as a remedy than wealthier ones who can afford to have better insulation or other technologies that help reduce noise. Alternatively, the funds also can be used to improve research and development as Burtraw and Sekar (2013), which can be used to directly improve the aviation industry and technology of the United States.

2.7 Airport Strategies to Combat Noise

Airports currently use a variety of strategies and policies to mitigate the effects of noise pollution on a community. Research has examined noise technologies extensively, but only relatively recently have particular policies been under scrutiny (Girvin, 2009; Netjasov, 2012). Even early aviation policies focused on the reduction of noise through technological improvements of aircraft alone (Girvin, 2009); however, this is no longer the only area targeted, as directed by ICAO on the balanced approach to noise management. Netjasov (2012) evaluated the various policies airports around the world choose to implement through evaluation of the Boeing database of world airports. Through evaluation of the noise database, Netjasov (2012) discovered 18 different policy measures aimed at reducing noise. These policy measures were noise abatement procedures, engine run-up restrictions, preferential runways, airport curfews, noise charges, APU operating restrictions, noise level limits, ICAO 16 Chapter 3/Chapter 2 restrictions, operating quotas, noise budget restrictions (i.e. slot allocation), sound insulation, purchase assurance for homeowners, avigation (overflight) easements, zoning laws, real estate/property disclosure laws, acquire land for noise compatibility, population within each noise contour relative to aircraft operations, and airport noise contour overlay maps (pp. 1078-1079). These 18 categories directly relate to the four guidelines for targeting noise reduction as established in the balanced approach model and discussed in Part 5 of Annex 16, Volume 1: source of the problem, managing land-use programs, operational procedures that focus on noise abatement, and aircraft operating restrictions (International Civil Aviation Organization, 2011). Netjasov (2012) found that the most common measures implemented were noise abatement procedures, engine run-up restrictions, preferential runways, and airport curfews and in North America 147 out of the 294 used between 1 and 4 measures. 116 airports used between 5 and 9 different strategies, and 2 airports used 14 of the 18 indicated strategies (Netjasov, 2012).

Focusing on policies within United States airports explicitly, Girvin (2009) stated that airports have a variety of policies that include noise limits that can involve fines for excessive noise as high as $500,000 and taxes for aircraft operation in the form of passenger facility charges. Curfews for operations and other operational restrictions are a direct form of noise restrictions by not allowing any operations at an airport during a specific time period. Various forms of noise reduction techniques that do not directly impact how an aircraft operator uses aircraft are preferential runways where air traffic control only allows operations at certain runways when conditions allow, and land use planning where airport managers can control the impact aircraft have on land in the airport environment (Girvin, 2009).

2.8 Chapter Summary

This chapter reviewed the existing literature on ICAO standards and implementation effectiveness and provided a historical context concerning the organizations and institutions involved in the aviation policy making, specifically concerning policies targeting a reduction in noise from aircraft or around airports. Issues about the challenges of regulating environmental impacts, along with attempted solutions, were discussed. Specifically, this chapter discussed the noise mitigation policies that have been addressed by ICAO through the balanced approach. These policy solutions will be explored further in the following chapters as an analytical feature to describe the state of noise pollution mitigation policies at the Class B and Class C airports in the United States. The next chapter describes the methodology that was used to complete the research.

CHAPTER 3. METHODOLOGY

This section describes the method that was used to analyze data in this research. It explains how the data were collected and organized. This chapter discusses the quantitative procedures that were necessary to answer the research questions.

3.1 Research Type and Framework

This research quantitatively explored noise mitigation policy data about airports and demographic U.S. Census data to determine the complex relationships concerning noise reduction policies surrounding local airport communities. The research questions focused on the evolution of the federal noise policies as the commercial air transport industry grew and aircraft become more frequently employed and larger. Quantitative techniques addressed the current status of airport noise policies at commercial airports; A type of cluster analysis, latent class analysis, was used with the intent to identify groups of airports implementing similar policies to mitigate noise pollution and a multinomial logistic regression was used to understand how community demographic variables and airport location affected the types of policies an airport may choose to implement to mitigate noise pollution.

3.2 Potential Threats to Validity

There were several issues that posed potential threats to the validity of the study. The aviation industry is a complex web of institutions and organizations that add to the challenge of finding policy solutions for issues like aircraft noise pollution. The Federal Aviation Administration (FAA) regulates the aviation industry in the United States and 14 CFR Part 36 establishes the federal regulations concerning aviation noise and maximum noise tolerances allowed for certification (Aurbach, 1977). Three potential solutions to reducing the environmental impact of aviation could be in the form of reducing the number of aircraft operations, changing the aircraft types being used to less polluting aircraft, or changing the regulations under which aircraft operate (Clarke, 2003). Airports, especially large international airports with a variety of operational goals ranging from private charter flights to transoceanic cargo flights, may be used as "laboratories for new strategies of both technological and social control" (Salter, 2008a, p. xi). Kingdon (2011) also noted that the interactions between four groups in particular drive the policy process. These are interest groups, experts, the media, and the government. These interactions were not explicitly evaluated in this study and may inhibit the ability to draw generalizable conclusions.

This study was limited in its necessity for subjective human evaluation as it is focused on pre-existing data collected and stored by external parties. Boeing collected the data that were used for the quantitative analysis. That information was voluntarily reported to Boeing by each airport under observation and therefore accuracy of the data is limited to what was reported. The data were collected in 2011 and changes may have occurred that were not reflected in the current analysis.

3.3 Data Collection

The study collected a variety of data to be used in a quantitative capacity. All data were available through government and industry archives and existing databases.

Local airport policies were evaluated using latent class analysis and multinomial logistic regression. Several online sources were used to collect data from 132 United States Class B and Class C airports. The data from these airports were scrutinized to determine which noise mitigation strategies are implemented at each airport. The data collected for this research concerned the presence and type of noise mitigation policies. Data about these noise policies were previously collected by Boeing on noise and emission policies at airports around the world. A limitation of these data are that the most recent iteration was collected in 2011 and not every airport had a document detailing the existence of noise and emissions policies. Because of this, only 132 airports were able to be used in the final analysis. Appendix A provides a detailed list of the locations and names of each airport studied. The noise policies collected for the 132 airports were categorized based on whether or not the report indicated the policy was in effect. These data were collected primarily from the website http://www.boeing.com/boeing/commercial/noise/list.page. The data collected consisted of items such as airport curfews, operating quota, engine run-up restrictions, APU operating restrictions, noise budget restrictions, noise surcharges, land use program information, noise monitors, flight track monitors, noise level limits, and aircraft stage restrictions. Land use programs can consist of elements such as sound insulation for residences and public buildings, easements for sound insulation, and zoning laws.

Whether or not a fine to an airline or aircraft operator for excessive noise production can be issued by the airport was noted as well

Demographic data for each airport were collected for use as covariates in analysis. These variables included population density, ethnic makeup, wealth status, household status and home values. The most recent, 2010, census data were used to identify population numbers.

3.4 Research Questions

The following is a review of the three research questions with a brief summary of the associated research method. These are:

Research Question 1. What are the current noise mitigation policy strategies utilized by large commercial airports in the United States and how frequently are they implemented?

Noise mitigation policies at the Class B and Class C civilian use airports in the United States were analyzed through latent class analysis. This procedure analyzed the various strategies employed at airports to reduce noise pollution that can include, but are not limited to, noise monitoring through sensors, fines for excessive noise, funding for insulation at schools and residences within determined noise contours, or aircraft routing procedures that direct aircraft over less populated areas when near a runway. The latent class analysis was used to determine airport clusters that implement similar policies.

Research Question 2. To what extent do regional and local community characteristics and local community aircraft noise complaints predict airport noise mitigation policies?

Using the results of the latent class analysis as an outcome variable (i.e., dependent variable), which organized noise policies into framework structures, a multinomial logistic regression was used with airport characteristics such as airport land use, airport hub size, and airport location in a rural or urban area, as well as community characteristics like region of country, population density, and median home values in the zip codes immediately surrounding the airport, and number of noise complaints to predict the odds of an airport implementing a certain set of policies. These predictors were chosen because of their ability to potentially shed light upon some of the reasons an airport may be more likely to implement a certain policy structure to combat noise pollution.

3.5 Research Method

Quantitative analyses for this research were useful for guiding categorization of noise policies in the United States. Descriptive statistics based on single variables are be presented first in Chapter 4. These statistics include maps of the United States providing visual representations of each state indicating the existence or non-existence of noise policies such as fines, noise monitors, and flight tracking systems.

A study by McKernan, Bernstein, and Fender (2005) created typologies based on welfare policies that were used as a framework for establishing typologies for noise policies. These typologies categorized states into groups with policies such as work requirements for welfare recipients, financial incentives to work, and allowable time on welfare ranging from relatively lenient to relatively strict. While McKernan, Bernstein, and Fender (2005) were able to use a cluster analysis technique because they used continuous variables; this study used a latent class analysis (LCA) technique that allowed for the use of categorical variables to create groups. Following the LCA, a multinomial logistic regression was used to predict particular airport policy clusters from the LCA based on particular airport community characteristics such as community population, airport land area, and rural or urban environment.

3.5.1 Latent Class Analysis

Typically, the term cluster analysis refers to the use of continuous variables to determine class membership (Vermunt & Magidson, 2002). It is possible to create cluster groups using a quantitative analysis of nominal or ordinal variables with latent class analysis (LCA) (McCutcheon, 1987). The independent variables may be useful for coded variables such as a Likert-type scale, or indicator variables created from a dichotomous categorical variable (Urick & Bowers, 2014; Mitchell, 2013). McCutcheon (1987) stated, "For example, the variable of interest might be a *typology* constructed from a combination of values of several constituent variables" (p. 6). An advantage of using LCA over other common techniques such as factor analysis is that LCA does not need to conform to the "assumption of multivariate normality nor the assumption of continuity of measurement" (McCutcheon, 1987, p. 7).

An advantage of using LCA is that it creates a set of outcomes that can be analyzed further through a multinomial logistic regression "to examine the extent that covariates influence the subgroups" (Urick & Bowers, 2014, p. 109).

3.5.2 Multinomial Logistic Regression

The final analysis conducted was a multinomial logistic regression. This regression served two purposes. Using Mitchell (2013) as a guide, a multinomial logistic regression allows the researcher to analyze the variables that predicted membership in the clusters of the LCA. More comparisons can be made between the groups by determining the likelihood of one variable occurring in a particular group as compared to the other possible groups.

The multinomial logistic regression is a complex statistical tool that expands the traditional logistic regression, where the response value can only take one of two values, to examine the possibility of an outcome belonging to one of multiple categories (Chatterjee & Hadi, 2006). The simple linear regression provides a basis for understanding any regression technique, but the utility of the multinomial logistic regression is more similar to the logistic regression. The basic model for the simple linear regression is: $\hat{Y} = \beta_0 + \beta_1 X_1$. When a regression model includes more than one independent variable, the regression model remains the same with the addition of the second variable multiplied with its beta coefficient (Sekaran & Bougie, 2009). The purpose of the linear regression is to fit a linear equation that explains the relationship between the independent variables and the intended outcome. Sekaran and Bougie (2009) explain “the individual regression coefficients indicate how much an increase of one unit in the independent variable would affect the dependent variable, assuming that all the other independent variables remain unchanged” (p. 351). The same logic applies to a logistic regression with differences in the overall model specification and the interpretation of the regression coefficients. The model for the logistic regression isln$(\frac{\hat{P}_i}{1-\hat{P}_i}) = \beta_0 + \beta_1 X_1$, and “is identical to the predictor side of the one-predictor OLS regression equation” (Cohen, Cohen, West, & Aiken, 2003, p. 487). The purpose of the logistic regression is different from linear regression because it does not attempt to predict a specific response for a given input, but instead determines the probability that the response will fall into a particular group (Chatterjee & Hadi, 2006). For the logistic equations given, the response predicts the probability of belonging to one of two groups, coded as 0 or 1 (Chatterjee & Hadi, 2006). The multinomial logistic regression predicts outcomes between two or more groups, so the modeled equation is only different in the natural log function for determining the outcome by determining probability based on the number of groups, but the basic equation remains the same (Long, 1997). As explained by Long (1997), “the multinomial logit model (MNLM) can be thought of as simultaneously estimating binary logits for all possible comparison among the outcome categories” (p. 149). For determining the likelihood of policy outcomes the multinomial logistic regression provides a useful way to understand where differences may occur between groups (Mitchell, 2013).

3.5.3 Assumptions of Multinomial Logistic Regression

The multinomial logistic regression must meet certain assumptions for validity. These assumptions are the same for a multinomial logistic regression as a dichotomous logistic regression. These assumptions include: 1) the outcomes for each case are independent and occur only once; 2) the model is accurately specified and contains all and only relevant predictors; 3) the response categories are mutually exclusive and collectively exhaustive; 4) the sample is large enough to produce accurate results (Wright, 1995). The independence of irrelevant alternatives (IIA) is one more assumption that must be made for the multinomial logistic regression that is not necessary for the dichotomous logistic regression (Long, 1997). The IIA means that if a new outcome becomes available, all probabilities are adjusted equally; if there are currently three outcomes in one situation then the probability of each outcome occurring is 1/3. However, if a fourth outcome becomes available then the probability of each outcome occurring should reduce to 1/4. If the probabilities of each outcome do not adjust equally then the assumption is violated and the original model is not specified accurately (Long, 1997). In a linear regression model there are four assumptions that include: 1) the model is linear; 2) independence of predictors; 3) the residuals of the model are normally distributed; 4) the residuals are distributed with equal variance (Cohen, Cohen, West, & Aiken, 2003).

3.6 Data Analysis

The LCA and the MNLR both required coding data from external, publically available resources. Permission was granted from Purdue University's Institutional Review Board (IRB) to conduct the study using the pre-existing data sources and the database owner with Boeing verified the noise policy airport data were available for public use.

3.6.1 LCA Method

Each of the 132 Class B and Class C airports were queried in the Boeing (2011) Airport Noise and Emissions Regulations database. Each airport in the database contained a description of each noise pollution mitigation policy that was used previously by Girvin (2009) and Netjasov (2012). Table 3.1 shows a list of the 19 identified potential policies.

Table 3.1

Potential noise pollution mitigation policies

Identified Airport Noise Pollution Mitigation Policies	
1	Noise Abatement Procedures
2	Engine Run-Up Restrictions
3	Preferential Runways
4	Airport Curfews
5	Noise Charges
6	APU Operating Restrictions
7	Noise Level Limits
8	ICAO Annex 16 Chapter 3/Chapter 2 Restrictions
9	Operating Quotas
10	Noise Budget Restrictions
11	Sound Insulation
12	Purchase Assurance for Homeowners

Table 3.1 Continued

	Identified Airport Noise Pollution Mitigation Policies
13	Avigation Easements
14	Zoning Laws
15	Real Estate/Property Disclosure Laws
16	Acquire Land for noise Compatibility
17	Population within Nose Contour Levels
18	Airport Noise Contour Overlay Maps

Two additional items, the presence of noise monitoring sensors in the community and flight tracking capabilities, were identified by the information cataloged by Boeing and were added to the LCA Analysis. One item, restrictions from ICAO Annex Chapter 3 was removed from the analysis because FAA regulation already mandated compliance and every airport was already in compliance. Therefore, a total of 19 potential policies were evaluated through the LCA. Table 3.2 shows the final list of variables included in the LCA. The outcome of the LCA was to categorize the 132 airports into clusters based on similar policy implementation. The results were not absolute and some subjective interpretation was required to make the best determination about the number of policy cluster groups within the 132 airports. As will be described in Chapter 4, the results appeared to indicate that there were six different airport policy implementation clusters and these six groups were used as outcomes for the MNLR. The number of policies implemented at each airport, and the percentage of overall policy implementation, as related to noise policy implementation, are provided in Appendix B. Also, indicated is whether the airport is classified as Class B or Class C. The airspace class was used as an auxiliary variable because it already separated the airport into basic operational sizes prior to running the analysis.

Table 3.2

Final LCA Variables

	Airport Noise Pollution Mitigation Policies for LCA
1	Noise Abatement Procedures
2	Engine Run-Up Restrictions
3	Preferential Runways
4	Airport Curfews
5	Noise Charges
6	APU Operating Restrictions
7	Noise Level Limits
8	Operating Quotas
9	Noise Budget Restrictions
10	Sound Insulation
11	Purchase Assurance for Homeowners
12	Avigation Easements
13	Zoning Laws
14	Real Estate/Property Disclosure Laws
15	Acquire Land for noise Compatibility
16	Population within Nose Contour Levels
17	Airport Noise Contour Overlay Maps
18	Noise Level Monitor Sensors
19	Flight Tracking System

3.6.2 MNLR Method

Based on the results of the LCA, a multinomial logistic regression (MNLR) was conducted based on certain airport characteristics and community demographic characteristics. The purpose of the MNLR was to determine the likelihood of airports with various community characteristics to implement a particular set of noise mitigation policies. The airport community characteristics were determined from the 2010 Census.

A limit was placed on the distance from an airport in order to determine the areas where noise impacts the community the most. For this study, a radius from the center of each airport of ten miles was chosen because aircraft are generally on or beginning a steady descent to the runway, and getting within only a few thousand feet of the ground. By five miles from the runway, aircraft have passed the final approach point and are usually fully configured for landing. Commercial aircraft taking off are generally able to get to higher altitudes and turn away from the airport centers within the ten-mile distance as well.

To get the community Census demographics for the ten-mile radius from each airport, the latitude and longitude for each airport were obtained from FAA information publically available. Airport data are updated in the Airport/Facility Directory every 56 days and includes the exact latitude and longitude coordinates for the central point of each airport. These coordinates were able to be input into the Circular Area Profile System (CAPS10) run by the University of Missouri. The Missouri Census Data Center (MCDC) hosts a software program that is able to aggregate the data from 2010 U.S. Census, and a second software program that aggregates the American Community Survey Data from 2010-2014 (Missouri Census Data Center, 2015; Missouri Census Data Center, 2014). Inputting the airport geographic coordinates, and stipulating a ten-mile radius, demographic data were able to be collected for each airport. The data included demographic, social, economic, and household information.

For the MNLR, because of the limited size of the sample, only a few indicators were able to be included in the analysis. The recommended number of observations per sample is ten (Schwab, 2002). Limiting the variables based on correlation and the uniqueness of the characteristic, seven community variables were included. These were population per square mile, percentage of community that reported being racially white, percentage of community households with kids less than 18 years of age, percentage of the community population that identified as poor (defined by the U.S. Census), the average medium home value reported in U.S. dollars for each community, and the percentage of the community population receiving public financial assistance.

In order to obtain more meaningful results comparisons of the variables were indicated as a percent value (i.e. percent white, percent of households with kids less than 18, percent poor, and the percent receiving public assistance) were divided by ten so that the outcome results interpretation were in relation to each ten percent increase. Many of the cities had several thousand people living within a square mile so the variable was divided by 1,000 so that each unit increase or decrease was related to 1,000 people living in a square mile. The median home values were also large and therefore the variable was divided by 10,000 for better comparisons about increases and decreases in home values.

In addition to the seven community variables, three airport characteristics were also included, with the region being coded into several groups as an indicator variable. For comparison purposes, the 132 airports used in the study were divided into four regions based on the U.S. Census categorizations. These regions were the Northeast, Midwest, South, and West (U.S. Census, 2015). The regions were coded so that each airport received a “1” for the region in which it was located. The airports were coded by their airline hub service as well, as determined by the FAA record of enplanements for the 2011 fiscal year (Federal Aviation Administration, 2012c). A hub is defined by the percentage of boarded passengers at a specific airports; a large hub has more than one percent of the country's total passenger enplanements; a medium has at least .25 percent, but less than 1 percent of total passenger enplanements; a small hub has at least .05 percent of total enplanements but less than .25 percent, and a non-hub classification means that the airport has more than 10,000 enplanements but less than .05 percent of all U.S. boarded passengers (Federal Aviation Administration, 2016). The large hubs and medium hubs were combined and coded as "1" while the small hubs and non-hubs were combined and coded with a "0." The third airport variable included in the analysis was whether or not the airport was classified as an international airport by serving an international destination. For the analysis an airport was coded with a "1" if it had an international component and "0" if it was strictly domestic. The indicator variables (region, hub size, and international service) were entered into the MNLR so that the South, small hubs or non-hubs, and domestic only service were the reference groups. Because the South was a specific region used for comparison it was not included in the model and the outcomes related to each of the other three regions were in relation to the South. Therefore, because the South was not directly included in the model, only 12 variables were entered into the final MNLR model and are shown in Figure 3.3.

Table 3.3

Variables Included in the Multinomial Logistic Regression

Multinomial Logistic Regression Variable
Population per square mile
Percent population reporting as white
Percent of household with kids less than 18
Average size of household
Percent of population reporting poor income
Median home values (U.S. Dollars)
Percent of population receiving public financial assistance
Region: Northeast
Region: Midwest
Region: West
Large and Medium Airport Hubs
Service to International Airports

3.7 Chapter Summary

Investigating the Boeing database on noise and emissions policies, noise mitigation policies at 132 Class B and Class C US airports that operate commercial airline service were analyzed through a combination of a latent class analysis (LCA) and multinomial logistic regression (MNLR). The LCA was used to determine common noise policy clusters implemented at the commercial airports (Mitchell, 2013; Urick and Bowers, 2014). Once the groups of airports were determined and assigned to their policy clusters, a multinomial logistic regression was conducted in order to determine the extent to which community demographic characteristics around each airport predicted a set of policies an airport may choose to implement.

CHAPTER 4. DATA AND FINDINGS

This chapter presents the results from the data analysis. The results from two quantitative analysis methods are presented with descriptive statistics preceding each formal analysis. The chapter begins with the presentation of data used to create airport policy classifications followed by the latent class analysis used to identify airport clusters using common noise mitigation strategies and policies. Aggregate community demographics are then presented and described, followed by the results of the multinomial logistic regression used to predict the likelihood of an airport implementing a certain set of noise mitigation policies based on community demographic characteristics.

4.1 Potential airport noise pollution mitigation policy strategies

Previous research has identified the current strategies implemented at airports around the world to reduce noise pollution on the surrounding airport communities. Girvin (2009) and Netjasov (2012) identified 18 noise mitigation policies implemented by airports around the world as categorized by Boeing. Two additional policies were identified from the airport data that were included for analysis. These were the implementation of noise monitoring systems and the implementation of flight tracking technology. One potential policy, ICAO Annex 16 Chapter 3/Chapter

2 Restrictions, was a minimum federal requirement by the Federal Aviation Administration (FAA) and therefore airport policy specification was necessary. It was not included as a potential policy variable in any analysis of US airport policies and resulted in 19 potential policy strategies that were considered for analysis. These 19 strategies, described in detail in Chapter 2, are presented and defined in Table 4.1.

Table 4.1

Noise Mitigation Policies

Noise Mitigation Policy	Type	Description
Noise Abatement Procedures	Procedural	Regulations directing aircraft around noise sensitive areas on approach and takeoff
Engine Run-Up Restrictions	Procedural	Policies restricting on-airport locations where engine power may be increased to test engine parameters
Preferential Runways	Procedural	Air Traffic Control designated runways for takeoff and landing when conditions permit normal operations
APU Restrictions	Operational	On-airport restrictions concerning the use of auxiliary power units to run systems prior to engine start-up
Excessive Noise Charges	Operational	Fines or charges to an airline or aircraft owner for exceeding specific noise limits
Noise Level Restrictions	Operational	Specific maximum decibel noise limitations specified for certain operations
Operating Quotas	Operational	Restrictions concerning the total number of aircraft allowed in a specified time period

Table 4.1 Continued

Noise Mitigation Policy	Type	Description
Noise Budgets	Operational	Slot allocation that specifies specific time limits for an aircraft to takeoff or land
Sound Insulation	Community	Programs for funding homes and schools determined to fall within a specified noise threshold
Homeowners Purchase Assurance	Community	Assurance to homeowners that they will be able to sell their homes at a fair value on the market or the airport will purchase the property
Avigation	Community	Specific rights with landowners allowing overflight of private property
Zoning Laws	Community	Development regulations specifying what can be built on particular properties
Real-Estate Disclosures	Community	Laws requiring all defects and facts about a property to be disclosed to a potential buyer
Acquire Land	Community	The ability for an airport to purchase land and property and relocate individuals within a defined noise contour
Population Data	Community	Determining the number of people within defined noise contours- usually 65 dBs and above
Noise Contour Maps	Community	Defined drawings about the average decibel thresholds over a 24-hour period usually above 65 dB
Noise Monitors	Tracking	Sensors placed on the airport and around the community to register aircraft dB readings
Flight Tracking System	Tracking	Sensors that record the exact aircraft flying in an area, usually with noise sensor information attached

Notes. Summarized from Netjasov (2012)

Each of the 132 airports (listed in Appendix A) considered in this study implemented a variety of the 19 potential noise mitigation policies. Policies limiting ground engine testing through engine run-ups were implemented the most often among airports (80%), while only one airport implemented any policy concerning noise budget restrictions (Table 4.2). Over 50 percent of the potential policies were implemented by 41 of the 132 airports as well. Table 4.3 shows the top ten airports with the most implemented noise policies and the bottom ten airports with the fewest implemented policies. Figure 4.1 shows the average noise mitigation policy implementation percentage at each airport. Many of the airports with the most policies appeared to be concentrated on the coasts, particularly the west coast. The southern United States appeared to contain the largest concentration of airports with only a small percentage of policies specifically directed at noise pollution mitigation.

Figure 4.1 Average policy implementation at 132 U.S. Class B and Class airports.

Table 4.2

Noise Mitigation Policies Implemented at Airports

Noise Mitigation Policy	# of Airports	Percent Implementation
Engine Run-Up Restrictions	105	0.80
Noise Abatement Procedures	97	0.73
Preferential Runways	93	0.70
Noise Contour Maps	75	0.57
Avigation	67	0.51
Zoning Laws	60	0.45
Acquire Land	60	0.45
Noise Monitors	60	0.45
Population Data	58	0.44
Sound Insulation	56	0.42
Flight Tracking System	56	0.42
Real-Estate Disclosures	41	0.31
Homeowner Purchase Assurance	24	0.18
Airport Curfews	22	0.17
Noise Level Restrictions	15	0.11
Excessive Noise Charges	13	0.10
APU Restrictions	11	0.08
Operating Quotas	5	0.04
Noise Budgets	1	0.01

Table 4.3

Top 10 and Bottom 10 Airport Noise Policy Implementations

Airport	Most Policies (Percent)	Airport	Fewest Policies (Percent)
SNA	0.89	JAX	0.05
SRQ	0.79	SAV	0.05
JFK	0.74	SFB	0.05
SAN	0.74	TYS	0.05
SFO	0.74	CHA	0.00
BNA	0.68	HSV	0.00
BUR	0.68	LBB	0.00
LAX	0.68	LFT	0.00
LGA	0.68	MYR	0.00
MSP	0.68	SHV	0.00

4.2 Review of Research Questions and Concepts

The remainder of this chapter presents the findings from the two research questions posed in Chapter 1. The following sections describe the results from the analyses and show the necessary information used to draw the conclusions discussed in Chapter 5.

4.3 Research Question 1

Research question 1 is, "What are the current policy strategies utilized by large commercial airports in the United States and how frequently are they implemented?" The results for this question were analyzed via the procedures described in Chapter 3. This section discusses the latent class analysis (LCA) used to categorize the data collected from the Boeing database on noise policies. This question focused on the status of policies actually implemented at 132 of the Class B and Class C airports in the United States. Based on the results of whether or not an airport implemented a particular noise mitigation policy, groupings of airports were made based on similar policy mitigation choices. In addition to presenting the general results of the LCA, the policy composition of each airport grouping is discussed.

4.3.1 Categorizing Noise Mitigation Policies at Airports

Based on the visual representation of overall noise mitigation policy implementation percentages at the Class B and Class C airports, there appeared to be variation in the types of policies in use. In order to explore this further, a latent class analysis (LCA) was conducted. The purpose of the LCA was to identify the airports that implemented similar policies. Using the Mplus statistical software package, the airport policy data were entered into the LCA model. The data were coded so that, for each of the 132 airports, “1” indicated the existence of the policy at the airport and “0” indicated an absence of the policy. Appendix C shows maps of the airports where each individual policy is implemented.

The airports were classified by the airspace under which they operate, Class B or Class C. The data consisted of 36 U.S. airports classified as Class B and 96 airports classified as Class C. This classification was used as an auxiliary variable that helped improve model accuracy.

The LCA determined that airport group clusters existed. While there is no concrete tool that determines the exact number of clusters in the data, there are statistical tests that aid in determining the best fit. The results of the LCA for 3, 4, 5, 6, and 7 class clusters are presented in Table 4.4. The analysis indicated that a 6-group classification was the best representation of policy differences at the Class B and Class C airports in the United States.

Each additional category tested showed significant improvement over the smaller category model. The Group 3 model resulted in a likelihood value of -1016.18 and, by Group 6, the value was reduced to -923.95. Reductions in Likelihood and AIC indicated better model fit. Entropy indicated the ability of the model to classify the observations and Group 6 recorded a high value of .95, similar to Group 4 and Group 5. Group 7 actually indicated the highest entropy, but the 139 free parameters used to estimate the classifications exceeded the 132 airport observations. The bootstrap technique compared the desired number of group clusters with one less.

Table 4.4

Latent Class Analysis Results

	Group3	Group4	Group5	Group6	Group7
Free Parameters	59.00	79.00	99.00	119.00	139.00
Likelihood	-1016.18	-975.65	-946.19	-923.95	-901.60
AIC	2150.36	2109.30	2090.37	2085.90	**2081.19**
BIC	**2320.44**	2337.04	2375.77	2428.95	2481.90
Adjusted BIC	2133.83	2087.16	2062.63	2052.55	**2042.24**
Entropy	0.93	0.95	0.95	0.95	**0.98**
Bootstrap	0.00	0.00	0.00	0.01	0.00

Note. Bold type indicates lowest values

A significant result indicated that the higher number of groups was better. All of the tested models indicated that they were significantly better than each lower group model ($p < .05$). Again, the bootstrap result for Group 7 indicated that the additional category was an improvement over Group 6 ($p < .001$) but was removed from consideration based on the overall interpretation of the group classification.

Once the analyses were complete and it was determined that clear group classifications existed, the models were used to create probability distributions about the likelihood of an airport group implementing a specific airport policy. Each group varied in the probabilities of implementing a specific policy and differences exist between groups regarding the likelihood of implementing a certain policy. Tables 4.5, 4.6, and 4.7 present the policy implementation probabilities for the 5-group, 6-group, and 7-group classifications. As indicated from the initial LCA analysis table (Table 4.4), the 6-group classification showed a grouping of policies distinctly different from the 5-group classification.

There were clear group differences in terms of the likelihood of policy implementation in all three classification tables (Table 4.5, Table 4.6, and Table 4.7). The colors provide a visual representation of the likelihood of policy implementation by an airport group cluster, from green representing lower probabilities, transitioning through yellow and orange, to red representing higher probabilities. As can be seen from Table 4.5, Table 4.6, and Table 4.7, the groups ranged from low policy implementation to likely implementation of almost all policies.

With the airports divided into seven groups, the analysis showed some overlap in some of the categories that made it difficult to determine specific differences. Group 6 and Group 7 had very similar results; Group 6 had three policies with an implementation likelihood of greater than .5 and Group 7 had two policies with an implementation likelihood of greater than .5. Of the 19 possible policies, Group 6 was likely not to implement 84 percent of the polices, whereas Group 7 was likely not to implement 90 percent. Group 3 and Group 4 had similar overlap on the policies with strong implementation likelihood as well. Even though the seven policy category classification analysis seemed to indicate the best categorization cluster, due to the difficulty to distinguish clear differences between some groups and the overstretching of the variables, the six-group airport cluster model was determined to be the best to proceed with analysis for the 132 airports.

Table 4.5

LCA Group 5 Probability Implementation Table

	Group1	Group2	Group3	Group4	Group5
Noise Abatement	0.85	1.00	1.00	0.50	0.46
Engine Run-Up	0.85	1.00	1.00	0.65	0.60
Preferential Runway	0.84	0.86	0.91	0.44	0.54
Airport Curfew	0.05	0.34	0.55	0.10	0.05
Noise Charges	0.00	0.26	0.46	0.00	0.00
APU Restrictions	0.03	0.29	0.09	0.00	0.00
Noise Level Limits	0.00	0.29	0.46	0.00	0.03
Operating Quotas	0.00	0.13	0.09	0.00	0.00
Noise Budgets	0.00	0.03	0.00	0.00	0.00
Sound Insulation	0.79	0.81	0.19	0.11	0.03
Homeowner Assurance	0.55	0.15	0.00	0.06	0.00
Avigation	1.00	0.71	0.00	0.55	0.03
Zoning	0.82	0.64	0.00	0.50	0.08
Real Estate Disclosure	0.75	0.37	0.00	0.20	0.03
Ability to Acquire Land	0.93	0.62	0.00	0.40	0.05
Known Area Populations	0.90	0.74	0.09	0.21	0.00
Noise Contour Maps	0.73	0.97	0.09	1.00	0.00
Noise Monitors	0.46	1.00	1.00	0.00	0.08
Flight Tracking Systems	0.40	0.97	1.00	0.00	0.06

Note. The colors in the graph range as indicated below:

0.00	0.20	0.40	0.60	0.80	1.00
0.10	0.30	0.50	0.70	0.90	

Table 4.6

LCA Group 6 Probability Implementation Table

	Group1	Group2	Group3	Group4	Group5	Group6
Noise Abatement	1.00	1.00	1.00	1.00	0.51	0.47
Engine Run-Up	0.96	1.00	1.00	0.94	0.65	0.62
Preferential Runway	0.93	0.82	0.91	0.87	0.54	0.52
Airport Curfew	0.08	0.55	0.56	0.18	0.10	0.05
Noise Charges	0.00	0.70	0.47	0.00	0.00	0.00
APU Restrictions	0.07	0.27	0.09	0.34	0.00	0.00
Noise Level Limits	0.00	0.79	0.47	0.00	0.00	0.03
Operating Quotas	0.00	0.35	0.09	0.00	0.00	0.00
Noise Budgets	0.00	0.09	0.00	0.00	0.00	0.00
Sound Insulation	1.00	0.91	0.17	0.60	0.27	0.00
Homeowner Assurance	0.62	0.19	0.00	0.00	0.18	0.00
Avigation	1.00	0.73	0.00	0.59	0.75	0.03
Zoning	0.75	0.90	0.00	0.54	0.62	0.09
Real Estate Disclosure	0.67	0.55	0.00	0.22	0.41	0.04
Ability to Acquire Land	1.00	0.82	0.00	0.26	0.65	0.02
Known Area Populations	0.88	0.82	0.09	0.68	0.47	0.00
Noise Contour Maps	0.86	1.00	0.09	0.86	0.81	0.08
Noise Monitors	0.69	1.00	1.00	1.00	0.04	0.08
Flight Tracking Systems	0.62	1.00	1.00	0.93	0.04	0.05

Note. The colors in the graph range as indicated below:

0.00–0.20	0.20–0.40	0.40–0.60	0.60–0.80	0.80–1.00
0.10	0.30	0.50	0.70	0.90

Table 4.7

LCA Group 7 Probability Implementation Table

	G1	G2	G3	G4	G5	G6	G7
Noise Abatement	1.00	0.80	1.00	1.00	1.00	0.48	0.46
Engine Run-Up	1.00	0.80	0.93	1.00	1.00	0.67	0.60
Preferential Runway	0.78	0.75	0.86	0.91	0.95	0.48	0.54
Airport Curfew	0.56	0.05	0.16	0.56	0.19	0.09	0.05
Noise Charges	0.67	0.00	0.00	0.47	0.10	0.00	0.00
APU Restrictions	0.22	0.05	0.36	0.09	0.09	0.00	0.00
Noise Level Limits	1.00	0.00	0.00	0.47	0.00	0.00	0.03
Operating Quotas	0.44	0.00	0.00	0.09	0.00	0.00	0.00
Noise Budgets	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Sound Insulation	0.89	0.70	0.57	0.18	1.00	0.15	0.03
Homeowner Assurance	0.11	0.40	0.00	0.00	0.64	0.10	0.00
Avigation	0.67	1.00	0.56	0.00	1.00	0.58	0.03
Zoning	0.89	0.80	0.58	0.00	0.74	0.48	0.08
Real Estate Disclosure	0.56	0.71	0.23	0.00	0.64	0.24	0.03
Ability to Acquire Land	0.78	1.00	0.20	0.00	1.00	0.39	0.05
Known Area Populations	0.89	1.00	0.68	0.09	0.77	0.20	0.00
Noise Contour Maps	1.00	0.70	0.84	0.09	0.90	1.00	0.00
Noise Monitors	1.00	0.25	1.00	1.00	0.90	0.00	0.08
Flight Tracking Systems	1.00	0.00	0.93	1.00	1.00	0.05	0.06

Note. The colors in the graph range as indicated below:

0.00 .20 .40 .60 0.80 1.00

0.10 0.30 0.50 0.70 0.90

4.3.2 LCA Results for 6 Policy Categories

The LCA model determined to best categorize the 132 Class B and Class C airports in the U.S. was the six-group model. As shown in Table 4.6, each classification coincides with the likelihood of an airport in that group implementing a specific policy. The group classifications ranged from low likelihood of any policy implementation to high likelihood of implementing many policies together. The groups discussed earlier were rearranged in Table 4.8 so that Group 1 was low likelihood and Group 6 was high likelihood. The group orders were changed so that Group 1 was not likely to implement any specific set of policies. Group 2 was only potentially likely to implement procedural policies such as noise abatement procedures, engine run-up procedures, and preferential runway operations. Group 3 was likely to implement the procedural policies in addition to the noise monitoring and flight tracking systems. With likelihood implementation probabilities above .5, Group 4, in addition to the procedural policies and the monitoring systems, was more likely than not to implement some community noise mitigation policies such as sound insulation programs and airport acquisition of land. Group 5 was likely to implement everything except policies that target operational awareness by the airline or aircraft owner such has noise level limits and noise charges. Group 6 was likely to implement almost all potential noise mitigation policies.

Table 4.8

LCA Group 6 probability implementation arranged from low to high

	G1 (6*)	G2 (5*)	G3 (3*)	G4 (4*)	G5 (1*)	G6 (2*)
Noise Abatement	0.47	0.51	1.00	1.00	1.00	1.00
Engine Run-Up	0.62	0.65	1.00	0.94	0.96	1.00
Preferential Runway	0.52	0.54	0.91	0.87	0.93	0.82
Airport Curfew	0.05	0.10	0.56	0.18	0.08	0.55
Noise Charges	0.00	0.00	0.47	0.00	0.00	0.70
APU Restrictions	0.00	0.00	0.09	0.34	0.07	0.27
Noise Level Limits	0.03	0.00	0.47	0.00	0.00	0.79
Operating Quotas	0.00	0.00	0.09	0.00	0.00	0.35
Noise Budgets	0.00	0.00	0.00	0.00	0.00	0.09
Sound Insulation	0.00	0.27	0.17	0.60	1.00	0.91
Homeowner Assurance	0.00	0.18	0.00	0.00	0.62	0.19
Avigation	0.03	0.75	0.00	0.59	1.00	0.73
Zoning	0.09	0.62	0.00	0.54	0.75	0.90
Real Estate Disclosure	0.04	0.41	0.00	0.22	0.67	0.55
Ability to Acquire Land	0.02	0.65	0.00	0.26	1.00	0.82
Known Area Populations	0.00	0.47	0.09	0.68	0.88	0.82
Noise Contour Maps	0.08	0.81	0.09	0.86	0.86	1.00
Noise Monitors	0.08	0.04	1.00	1.00	0.69	1.00
Flight Tracking Systems	0.05	0.04	1.00	0.93	0.62	1.00

Note. *Indicates the original group number as determined by the LCA

The colors in the graph range as indicated below:

0.00	0.20	0.40	0.60	0.80	1.00
0.10	0.30	0.50	0.70	0.90	

4.4 <u>Airports by Policy Grouping</u>

The LCA determined the most likely group to which an airport belonged. Using those probabilities to determine the airports in each category, the airports in each group classification are discussed below.

4.4.1 Group 1 Airports

Group 1 airports were those that were not likely to implement many policies targeting the reduction of noise pollution on a community. A visual representation of these airports, compared to the other groups, is provided in Figure 4.2. These airports appeared to be clustered east of the Mississippi River, particularly in the Southeastern United States. They also tended to be in small cities and less densely populated locations, compared to the other clusters. Table 4.9 presents the airports in this group.

Figure 4.2 Group 1 airports displayed by location.

Table 4.9

Group 1 Airports

Airport ID	City	State	Airport Name
ACY	Atlantic City	NJ	Atlantic City International Airport
ALB	Albany	NY	Albany International Airport
ANC	Anchorage	AL	Ted Stevens Anchorage International Airport
ATL	Atlanta	GA	Hartsfield-Jackson Atlanta International Airport
AVL	Asheville	NC	Asheville Regional Airport
BGR	Bangor	ME	Bangor International Airport
BHM	Birmingham	AL	Birmingham-Shuttlesworth International Airport
CAE	Columbia	SC	Columbia Metropolitan Airport
CAK	Akron	OH	Akron-Canton Regional Airport
CHA	Chattanooga	TN	Lovell Field Airport

Table 4.9 continued

Airport ID	City	State	Airport Name
CHS	Charleston	SC	Charleston Air Force Base/International Airport
CID	Cedar Rapids	IA	The Eastern Iowa Airport
CMI	Champaign	IL	University of Illinois-Willard Airport
DSM	Des Moines	IA	Des Moines International Airport
ELP	El Paso	TX	El Paso International Airport
EVV	Evansville	IN	Evansville Regional Airport
GRB	Green Bay	WI	Austin-Straubel International Airport
GSO	Greensboro	NC	Piedmont Triad International Airport
HRL	Harlingen	TX	Valley International Airport
HSV	Huntsville	AL	Huntsville International Airport-Carl T Jones Field
ICT	Wichita	KA	Wichita Dwight D Eisenhower National Airport
ISP	Long Island	NY	Long Island Mac Arthur Airport
JAN	Jackson	MS	Jackson-Medgar Wiley Evers International Airport
JAX	Jacksonville	FL	Jacksonville International Airport
LAN	Lansing	MI	Capital Region International Airport
LBB	Lubbock	TX	Lubbock Preston Smith International Airport
LFT	Lafayette	LA	Lafayette Regional Airport/Paul Fournet Field
LIT	Little Rock	AR	Bill and Hillary Clinton National Airport/Adams Field
MCI	Kansas City	MO	Kansas City International Airport
MYR	Myrtle Beach	SC	Myrtle Beach International Airport
OMA	Omaha	NE	Eppley Airfield
ORF	Norfolk	VA	Norfolk International Airport
PNS	Pensacola	FL	Pensacola International Airport
RIC	Richmond	VA	Richmond International Airport
ROC	Rochester	NY	Greater Rochester International Airport
SAV	Savannah	GA	Savannah/Hilton Head International Airport
SFB	Orlando	FL	Orlando Sanford International Airport
SHV	Shreveport	LA	Shreveport Regional Airport
SPI	Springfield	IL	Abraham Lincoln Capital Airport
TYS	Knoxville	TN	Mc Ghee Tyson Airport

4.4.2 Group 2 Airports

Group 2 airports were those that were not likely to implement many policies targeting the reduction of noise pollution on a community, but were more likely than Group 1 to implement some particular policies. The highest likelihood of implementing a particular policy, noise contour maps, was .81. This group was somewhat likely (a probability from greater than .50 to .75) to implement some community policies and procedural policies. A visual representation of these airports, compared to the other groups, is provided in Figure 4.3. These airports appeared to be similar to Group 1 where the airport locations were still in less densely populated cites than the groups that use more policy strategies to mitigate noise pollution. These airports in Group 2, however, were more widespread across the United States than those airports in Group 1. Airports in Group 2 covered nearly every region of the country, except for the Southwest. Table 4.10 presents the airports in this group.

Figure 4.3 Group 2 airports displayed by location.

Table 4.10

Policy Group 2 Airports

Airport ID	City	State	Airport Name
BIL	Billings	MT	Billings Logan International Airport
BOI	Boise	ID	Boise Air Terminal/Gowen Field
BTV	Burlington	VT	Burlington International Airport
COS	Colorado Springs	CO	City of Colorado Springs Municipal Airport
CRP	Corpus Christi	TX	Corpus Christi International Airport
CRW	Charleston	WV	Yeager Airport
DAB	Daytona Beach	FL	Daytona Beach International Airport
FAY	Fayetteville	NC	Fayetteville Regional Airport/Grannis Field
FWA	Fort Wayne	IN	Fort Wayne International Airport
GEG	Spokane	WA	Spokane International Airport
GRR	Grand Rapids	MI	Gerald R Ford International Airport
GSP	Greenville	SC	Greenville Spartanburg International Airport
HOU	Houston	TX	William P Hobby Airport
IAD	Washington D.C.	D.C.	Washington Dulles International Airport
IAH	Houston	TX	George Bush Intercontinental
LNK	Lincoln	NE	Lincoln Airport
MEM	Memphis	TN	Memphis International Airport
MLI	Moline	IL	Quad City International Airport
MOB	Mobile	AL	Mobile Regional Airport
MSN	Madison	WI	Dane County Regional Airport-Truax Field
OKC	Oklahoma City	OK	Will Rogers World Airport
ROA	Roanoke	VA	Roanoke Regional Airport/Woodrum Field
RSW	Fort Myers	FL	Southwest Florida International Airport
SBN	South Bend	IN	South Bend International Airport
SGF	Springfield	MO	Springfield-Branson National Airport
SYR	Syracuse	NY	Syracuse Hancock International Airport
TLH	Tallahassee	FL	Tallahassee International Airport

4.4.3 Group 3 Airports

Group 3 airports were those more likely than Group 1 or Group 2 to implement certain policies. Group 3 was the first group to have certainty about the likelihood of implementing noise mitigation policies. Group 3 airports were very likely (probabilities greater than .90) to implement procedural and tracking policies. A visual representation of these airports, compared to the other groups, is provided in Figure 4.4. This group included airports that were located in some of the larger cities in the United States but were located mostly in the East and Midwest United States. Only one airport, San Jose International, was located on the West coast. These airports appeared to be locations that are either a secondary airport to a larger city or the airports are outside of the city center. Table 4.11 presents the airports in this group.

Figure 4.4 Group 3 airports displayed by location.

Table 4.11

Policy Group 3 Airports

Airport ID	City	State	Airport Name
BOS	Boston	MA	General Logan International Airport
CLT	Charlotte	NC	Charlotte/Douglas International Airport
CMH	Columbus	OH	Port Columbus International Airport
DAL	Dallas	TX	Dallas Love Field Airport
DCA	Washington D.C.	D.C.	Washington National Airport

Table 4.11 continued

Airport ID	City	State	Airport Name
DEN	Denver	CO	Denver International Airport
FLL	Fort Lauderdale	FL	Fort Lauderdale International Airport
MDW	Chicago	IL	Chicago Midway International Airport
MSY	New Orleans	LA	New Orleans International Airport
PBI	Palm Beach	FL	Palm Beach International Airport
SJC	San Jose	CA	San Jose International Airport

4.4.4 Group 4 Airports

Group 4 airports were very likely to implement the same procedural and tracking policies that were identified by Group 3. In addition to these policies, Group 4 airports were somewhat likely to implement some community policies as well. A visual representation of these airports, compared to the other groups, is provided in Figure 4.5. The airports in the group were spread around the country and included some of the more densely populated cities and were located mostly near the coastlines. These airports were also in large cities that operated service to international destinations. Table 4.12 presents the airports in this group.

Figure 4.5 Group 4 airports displayed by location.

Table 4.12

Policy Group 4 Airports

Airport ID	City	State	Airport Name
ABE	Allentown	PA	Lehigh Valley International Airport
ABQ	Albuquerque	NM	Albuquerque International Sunport Airport
AUS	Austin	TX	Austin-Bergstrom International Airport
MIA	Miami	FL	Miami International Airport
MRY	Monterey	CA	Monterey Regional Airport
OGG	Kahului	HI	Kahului Airport
ORD	Chicago	IL	Chicago O'Hare International Airport
PDX	Portland	OR	Portland International Airport
PHL	Philadelphia	PA	Philadelphia International Airport
PVD	Providence	RI	Theodore Francis Green State Airport
PWM	Portland	ME	Portland International Jetport
RNO	Reno	NV	Reno/Tahoe International Airport
SAT	San Antonio	TX	San Antonio International Airport
STL	St. Louis	MI	Lambert-St Louis International Airport
TPA	Tampa	FL	Tampa International Airport

4.4.5 Group 5 Airports

Group 5 airports were likely to implement nearly all policy categories except the operational policies. Airports in this group implemented policies that directed aircraft movements away from population centers, invested in the community, and tracked the flights. A visual representation of these airports, compared to the other groups, is provided in Figure 4.6. These airports appeared to be clustered more in the Southwest and Northeast United States These airports appeared to be larger size cities with airports with busy operations. Table 4.13 presents the airports in this group.

Figure 4.6 Group 5 airports displayed by location.

Table 4.13

Policy Group 5 Airports

Airport ID	City	State	Airport Name
BDL	Hartford	CT	Bradley International Airport
BNA	Nashville	TN	Nashville International Airport
BTR	Baton Rouge	LA	Baton Rouge Metropolitan Airport
BUF	Buffalo	NY	Buffalo Niagara International Airport
BWI	Baltimore	MD	Baltimore/Washington International Airport
CLE	Cleveland	OH	Cleveland-Hopkins International Airport
CVG	Covington	KY	Cincinnati International Airport
DFW	Dallas	TX	Dallas/Fort Worth International Airport
DTW	Detroit	MI	Detroit Metropolitan Wayne County Airport
FAT	Fresno	CA	Fresno Yosemite International Airport
HNL	Honolulu	HI	Honolulu International Airport
IND	Indianapolis	IN	Indianapolis International Airport
LAS	Las Vegas	NV	McCarran International Airport
LAX	Los Angeles	CA	Los Angeles International Airport
MCO	Orlando	FL	Orlando International Airport
MHT	Manchester	NH	Manchester Airport
MKE	Milwaukee	WI	General Mitchell International Airport
MSP	Minneapolis	MN	Minneapolis-St Paul International Airport
ONT	Ontario	CA	Ontario International Airport
PHX	Phoenix	AZ	Phoenix Sky Harbor International Airport
PIT	Pittsburgh	PA	Pittsburgh International Airport
SBA	Santa Barbara	CA	Santa Barbara Municipal Airport

Table 4.13 continued

Airport ID	City	State	Airport Name
SDF	Louisville	KY	Louisville International Airport
SLC	Salt Lake City	UT	Salt Lake City International Airport
SMF	Sacramento	CA	Sacramento International Airport
TOL	Toledo	OH	Toledo Express Airport
TUL	Tulsa	OK	Tulsa International Airport
TUS	Tucson	AZ	Tucson International Airport

4.4.6 Group 6 Airports

Group 6 airports were those that were likely to implement nearly all policies targeting the reduction of noise pollution on a community. There were only 4 specific policies with a probability of implementation less than .5, but 7 policies with a probability of implementation greater than .9. Group 6 was the only group to target operational policies that result in economic burdens on the airlines or aircraft owners through fines for excessive noise production. A visual representation of these airports, compared to the other groups, is provided in Figure 4.7. These airports appeared to be in larger coastal cities in the East and the West. The airports also appeared to be airports with larger operations and international service. Airports in the Midwest were entirely absent in this cluster of airports. Table 4.14 presents the airports in this group.

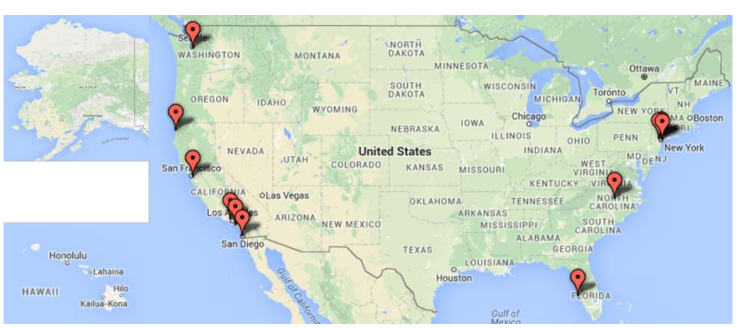

Figure 4.7 Group 6 airports displayed by location.

Table 4.14

Policy Group 6 Airports

Airport ID	City	State	Airport Name
BUR	Burbank	CA	Bob Hope Airport
EWR	Newark	NJ	Newark Liberty International Airport
JFK	New York	NY	John F Kennedy International Airport
LGA	New York	NY	LaGuardia Airport
OAK	Oakland	CA	Metropolitan Oakland International Airport
RDU	Raleigh	NC	Raleigh-Durham International Airport
SAN	San Diego	CA	San Diego International Airport
SEA	Seattle	WA	Seattle Tacoma International Airport
SFO	San Francisco	CA	San Francisco International Airport
SNA	Santa Ana	CA	John Wayne-Orange County Airport
SRQ	Sarasota	FL	Sarasota/Bradenton International Airport

4.5 Research Question 2

The second research question addressed in this study is, "To what extent do regional and local community characteristics predict airport noise mitigation policies?" The purpose of the implemented noise mitigation policies at airports is to reduce the noise pollution that impacts the surrounding airport communities. The sections above describe the airport classification results (i.e. airports that share similar policy strategies).

4.5.1 Airport Community Demographics

The demographic information for each surrounding airport within a radius of ten miles was obtained from the 2010 U.S. census data. Ten miles was determined as the area of interest because of the general sequence for aircraft approaching an airport. Aircraft begin their approach profiles for landing on a runway about ten miles away from the airport. From that point, the aircraft are generally on a steady descent path as the get closer to the airport. Table 4.15 shows the average population demographics within the ten-mile distance. There were, on average, 628,146 people within ten miles of the 132 airports; however, the data collected by the U.S. Census varied widely and the community around the airport in Bangor, Maine had around 86,000 people, while New York, New York had over 7 million people. The population per square mile was a better indicator of the population density in a particular community and within the ten-mile radius; there was an average of 2,459 people per square mile. Within ten miles of the 132 airports considered in this study, on average, 42 percent of the population was in a racial minority population and 17 percent were identified as living in poor economic conditions.

Table 4.15

Community Demographics within 10 Miles of an Airport (N = 132)

Demographic Variable	10 Miles	SD
Area (sq. miles)	296.71	50.97
Population	628146.69	802606.70
Population per square mile	2459.15	3297.8903
Median Age	36.65	3.00
Minority	0.42	0.20
Percent of households with kids under 18	0.28	0.04
Percent single occupant households	0.29	0.04
Percent over 65	0.20	0.04
Average Household Size	2.51	0.22
Median Household Income	55528.71	12676.78
Average Household Income	70169.54	14673.23
Population in poverty	619679.52	801443.80
Population poor	108201.00	154447.66
Percent poor	0.17	0.05

Table 4.15 continued

Demographic Variable	10 Miles	SD
Median home value	227607.61	137570.36
Average home value	251041.76	153574.79
Percent of Households using Public Assistance	0.03	0.01
Average Household Public Assistance	3580.30	923.57

Table 4.16 shows the average demographic results and the airport characteristics for the variables considered in the multinomial logistic regression based on each policy outcome group. The groups were organized from the implementation of the fewest policies (Group 1) to the implementation of the most policies (Group 6).

Table 4.16

Airport Community Demographics within 10 Miles of an Airport

	G1	G2	G3	G4	G5	G6
Population[a]	8.40	2.47	4.22	2.64	1.15	1.15
Median Age	37.55	36.26	35.99	37.65	36.53	36.57
Percent White	0.43	0.57	0.45	0.52	0.62	0.65
Households with kids	0.28	0.29	0.29	0.27	0.28	0.29
Household Size	2.61	2.57	2.56	2.51	2.47	2.46
Percent poor	0.16	0.17	0.16	0.17	0.18	0.18
Median home value[b]	45.89	23.37	29.21	27.06	16.54	16.89
Public assistance	0.03	0.04	0.02	0.03	0.03	0.03
Region: Midwest	0	0.25	0.18	0.13	0.28	0.25
Region: Northeast	0.27	0.18	0.09	0.27	0.13	0.11
Region: South	0.18	0.21	0.55	0.27	0.56	0.5
Region: West	0.55	0.36	0.18	0.33	0.03	0.14
Large and medium hubs	0.91	0.71	1	0.73	0.13	0.18
International service	0.82	0.86	0.91	0.8	0.59	0.54

The variables such as the percent of households with kids less than 18 years old (*M* = .27-.29), percent poor (*M* = .16-.18), and the percent of households using public assistance were nearly the same across all groups (*M* = .02-.04).

4.5.2 Multinomial Logistic Regression Results

The six airport group clusters were used as the outcome variable in a multinomial logistic regression. The data were collected and analyzed through the methods described in Chapter 3. The purpose of the logistic regression was to determine if community characteristics in the vicinity of the airports predicted the likelihood of belonging to a group classification that implemented a particular set of noise pollution mitigation policies. In order to understand the impact of noise on communities as aircraft get closer to airports, the multinomial logistic regressions were conducted based on the characteristics of populations. The results from the MNLR are shown in Table 4.17 (ten-mile radius). In each table the reference group was the lowest policy implementation group (Group 1). The coefficients (*b*), p-value level (*p*) standard errors (*se*), and odds ratios (*OR*) are presented for each variable. The odds ratios are the exponentiated values of the coefficients and a significant result means that within the 95 percent confidence intervals, a value of 1.00 is not included. An odds ratio of 1.00 means that the likelihood of belonging to one group compared to another is the exact same.

Group 6 was the cluster of airports likely to implement the most noise policies and there were several significant predictors of belonging to Group 6 compared to Group 1. Population per square mile ($b = 1.81$, $se = .52$, $p < .001$) indicated that for every 1,000 persons increase in population per square mile, the odds of belonging to Group 6 over Group 1 increased by 6.11. Airports located in the West as compared to the South (*b* = 578, *se* = 2.53, $p < .05$) and airports that were classified as large or medium size airport hubs (*b* = 3.83, *se* = 2.83, $p < .05$) were also more likely to belong to Group 6 as compared to Group 1.

Airports in the West, as compared to the South, were over 300 times more likely to belong to Group 6 than Group 1. As was seen in Table 10, over half of the airports in Group 6 were in the West and over half of the airports in the South were in Group 1. The ratio of airports belonging to the West over the South was greater in Group 6.

Group 5, the group likely to implement a variety of noise mitigation policies next to Group 6, had the same significant indicators predicting the likelihood of belonging to Group 5 over Group 1. An increase in population (*b* = .99, *se* = .44, $p < .05$), a greater ratio of airport in the West than the South (*b* = 4.20, *se* = 1.69, $p < .05$), and an airport operating as a large or medium size hub (*b* = 2.65, *se* = .91, $p < .01$), were all positively associated with belonging to Group 5 over Group 1. For every increase in the population per square mile by 1,000 people, the likelihood of belonging to Group 5 over Group 1 increased by 2.64 times. Group 4, was also similar to Group 5 and Group 6, however, the airports in the Northeast, compared to the South were more likely to be in Group 4 than Group 1(*b* = 3.31, *se* = 1.53, $p < .05$).

Table 4.17

Multinomial Logistic Regression for Airport Communities within 10 Miles (N = 132)

	GROUP 2[1]					GROUP 3[1]					GROUP 4[1]				
	b	se	*p*	OR		b	se	*p*	OR		b	se	*p*	OR	
Population[a]	0.40	0.47		0.59	3.76	1.43	0.49	**	1.58	10.97	0.97	0.46	*	1.08	6.48
White[b]	0.62	0.37	+	0.91	3.81	0.05	0.62		0.31	3.55	-0.09	0.49		0.35	2.40
Kids[c]	3.49	2.15		0.48	>1000	1.04	2.70		0.01	561.60	-1.84	2.51		0.00	21.56
Household[d]	-5.50	4.48		0.00	26.87	-6.20	6.52		0.00	715.71	-1.47	5.55		0.00	>1000
Poor[e]	2.47	1.27	+	0.98	142.19	0.81	2.04		0.04	122.26	0.79	1.59		0.10	49.85
Home Value[f]	0.03	0.07		0.91	1.17	0.06	0.08		0.91	1.24	0.03	0.07		0.90	1.18
Public Asst[g]	-2.48	2.59		0.00	13.43	-11.69	6.20	+	0.00	1.59	-5.63	4.15		0.00	12.24
Midwest[2]	-0.72	0.84		0.09	2.55	0.63	1.71		0.07	52.95	0.97	1.41		0.17	41.45
Northeast[2]	0.13	1.12		0.13	10.33	1.05	2.39		0.03	311.24	3.31	1.53	*	1.35	553.80
West[2]	1.93	1.52		0.35	133.87	4.15	2.18	+	0.89	>1000	5.03	1.89	**	3.79	>1000
Airport Hub	0.86	0.86		0.44	12.69	17.22	>1000		0.00	>1000	2.56	1.08	*	1.54	108.02
International	-0.19	0.59		0.26	2.66	1.14	1.62		0.13	74.60	0.71	1.11		0.23	17.69
Constant	-5.28	8.34				-8.57	1065.62				3.36	12.97			

Note. [1]Group 1 is the reference group. LR $Chi^2(60) = 162.02$. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.
Pseudo $R^2 = .37$
Log Likelihood = -140.66
[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table 4.17 continued

	GROUP 5[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	0.99	0.44	*	1.14	6.29	1.81	0.52	***	2.21	16.73
White[b]	0.58	0.44		0.76	4.20	0.64	0.68		0.50	7.12
Kids[c]	-1.48	2.16		0.00	>1000	-1.93	2.83		0.00	>1000
Household[d]	3.16	4.75		0.00	>1000	-2.17	7.06		0.00	>1000
Poor[e]	1.73	1.41		0.00	>1000	-1.64	2.43		0.00	>1000
Home Value[f]	0.04	0.07		0.91	1.18	0.03	0.08		0.89	1.20
Public Asst[g]	-3.39	3.30		0.00	21.65	-10.08	6.43		0.00	12.49
Midwest[2]	0.81	1.15		0.24	21.52	-14.07	914.06		0.00	>1000
Northeast[2]	2.03	1.34		0.56	104.82	-0.23	2.51		0.01	109.25
West[2]	4.20	1.69	*	2.44	>1000	5.78	2.53	*	2.26	>1000
Airport Hub	2.65	0.91	**	2.37	84.83	3.83	1.83	*	1.28	>1000
International	1.18	0.92		0.53	19.83	0.39	1.72		0.05	42.80
Constant	-14.85	10.58				2.70	18.00			

Note. [1]Group 1 is the reference group. LR $Chi^2(60) = 162.02$. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Group 2 and Group 3 were not strong on noise mitigation policies in the airport communities. Group 3 was similar to Group 4, Group 5, and Group 6 because population per square mile (b =1.43, se = .49, p < .01) was still important in belonging to Group 3 over Group 1. For every population increase of 1,000 per square mile, the likelihood of an airport belonging to Group 3 as compared to Group 1 increased by 4.18. The ratio of airports belonging to the West over the South was also greater for Group 3 than airports belonging to the West over the South for Group 1 (b =4.15, se = 2.18, p < .10). These differences disappeared and the likelihood of belonging to Group 2 or Group 1 did not change based on population or region. Group 2 was unique in that it appeared that percentage of persons who reported being white and the percentage of persons who reported being poor on the U.S. Census impacted the group outcome compared to Group 1. For each ten percent increase in the number of white people living within 10 miles of the airport, the odds of belonging to Group 2 compared to Group 1 increased 1.85 times (b = .62, se = .37, p < .10); for each ten percent increase in the number of people reporting a poor income, the odds of belonging to Group 2 compared to Group 1 increased 11.8 times (b = 2.47, se = 1.27, p < .10). The unique indicator of Group 3 was percentage of households receiving public assistance. Each ten percent increase in that percentage indicated a decrease in the likelihood of belonging to Group 3 over Group 1 (b = -11.69, se = 6.20, p < .10). Despite these indicated trends, the average percentage of people falling into each category (4.16) were nearly identical when comparing to Group 1.

4.6 Changing the Reference Groups

All of the group comparisons examined in the previous sections were discussed in relation to the group of airports least likely to implement noise mitigation policies as the base comparison (Group 1). In order to make comparisons between groups not in Group 1 it was necessary to change the models to reflect that. The sections that follow describe the results after the remaining groups (Group 2, Group 3, Group 4, Group 5, and Group 6) were changed to the be the reference group for comparison purposes. The model interpretations remained the same and the overall model fit data remained the same.

4.6.1 Group 2 as reference

A closer examination of how each group related to each other required changing the base reference group and re-running the analysis. Changing the results to look at each group compared to Group 2 resulted in some similar results to Group 1. For a full depiction of the results table for Group 2 as reference see Appendix D.

Comparing Group 6 to Group 2, population per square mile, the percent of families with kids less than 18, and the West were indicative of belonging to a particular group. As population per square mile increased ($b = 1.40$, $se = .54$, $p < .05$) the odds of belonging to Group 6 increased; as the percentage of families with kids less than 18 increased, the odds of belonging to Group 6 decreased ($b = -5.42$, $se = 3.05$, $p < .10$); airports in the West, as compared to the South, were more likely to be in Group 6 than Group 2 ($b = 3.85$, $se = 2.30$, $p < .10$). As the percentage of families with kids less than 18 increased, the likelihood of being in Group 4 ($b = 1.40$, $se = .54$, $p < .05$) or Group 5 (*b* = 1.40, *se* = .54, $p < .05$) also decreased. Also, the airports in the West were more likely to be in Group 4 (*b* = 2.27, *se* = 1.35, $p < .10$) or Group 5 (*b* = 3.10, *se* = 1.59, $p < .10$) compared to airports in the South. The only apparent difference between Group 2 and Group 3 was concerning population. As population per square mile increased, the likelihood of belonging to Group 3 over Group 2 increased (*b* = 1.40, *se* = .54, $p < .05$).

4.6.2 Group 3 as reference

Changing the results to look at each group compared to Group 3 resulted in only a few differences. Group 3 was in the middle and differences between each group were less apparent than between Group 6 and Group 1. For a full depiction of the results table for Group 3 as reference see Appendix D. Group 1 and Group 2 were the only groups with significant results compared to Group 3. Population per square mile was significant for both Group 1 (*b* = -1.02, *se* = .52, $p < .05$) and Group 2 (-*b* = 1.43, *se* = .50, $p < .01$), meaning that for every increase per square mile in population by 1,000, the likelihood of being in Group 1 or Group 2 decreased by .24 and .36 times respectively. The comparisons between Group 3 and Group 1 were already presented earlier in the section and no other significant results were determined.

4.6.3 Group 4 as reference

Changing the results to look at each group compared to Group 4 resulted in some similar results to Group 1. For a full depiction of the results table for Group 4 as reference see Appendix D. As with Group 3 there were not a lot of statistically significant group comparisons except with Group 1 (already presented) and Group 2. Population per square mile increases resulted in a decrease in the likelihood of being in Group 1 compared to Group 4, but the opposite occurred with Group 6 ($b = .83$, $se = .34$, $p < .05$). For each increase by 1,000 people over the population per square mile, the likelihood of being in Group 6 compared to Group 4 increased 2.29 times. The population increase was not significant for Group 5, but the percent of white inhabitants was significant ($b = .67$, $se = .40$, $p < .10$). For each ten percent increase in the population of white people, the likelihood of being in Group 5 over Group 4 increased 1.95 times. Group 2 also indicated significant region differences when compared to Group 4. When compared to the South, the Northeast ($b = -3.18$, $se = 1.60$, $p < .05$) and the West ($b = -3.10$, $se =1.59$, $p < .10$) were both less likely to be in Group 2 than Group 4.

4.6.4 Group 5 as reference

Changing the results to look at each group compared to Group 5 resulted in some similar results to Group 1. For a full depiction of the results table for Group 6 as reference see Appendix D. Group 5 was the group likely to implement the most noise mitigation policies next to Group 6 and the most significant differences were found between Group 1 and Group 2, the least likely to implement noise mitigation policies. Airports that were in the West or were large or medium size hubs were less likely to be in Group 1 (as mentioned previously), but this was also true for being in Group 2 as well. Airports in the West, as compared to the South, were .10 times as likely to be in Group 2 ($b = -2.27$, $se = 1.35$, $p < .10$), meaning they were more likely to be in Group 5; airports that were large and medium size hubs were .17 times as likely to be in Group 2 (*b* = -1.80, *se* = .94, $p < .10$), meaning they were more likely to be in Group 5. Group 2 did appear to be more likely to favored over Group 5 as the percent of families with kids under 18 increased (*b* = 4.97, *se* = .2.48, $p < .05$). For each ten percent increase in the percentage of families with kids under 18, the likelihood of being in Group 2 increased 144 times. Airports were less likely to be in Group 4 than Group 5 as the population of white people living within the community increased (*b* = -.67, *se* = .40, $p < .10$); as the overall population per square mile increased, airports were more likely to be in Group 6 than Group 5 (*b* = .82, *se* = .33, $p < .05$).

4.6.5 Group 6 as reference

By presenting the comparisons to all other groups, Group 6 results were covered in depth. The table results are presented in Appendix D. However, it is important to note a few particular points because Group 6 was the upper end of the noise policy implementation spectrum. Group 6 contrasts with Group 1 and Group 2 the most and there were significant indicators that favor Group 6. These indicators were population per square mile, the West, and large and medium airport hubs. Compared to Group 2, there appeared to be an indicator that, as the percentage of families with kids under 18 increased, airports were more likely to belong to Group 2 than Group 6 (*b* = 5.42, *se* = 3.05, $p < .10$). Population per square mile was important and a positive indicator for Group 6 compared to all groups except Group 3 (*b* = .38, *se*= .31, *p* < *ns*).

4.7 Chapter Summary and Summary of Findings

This chapter presented the results from the latent class analysis (LCA) and the multinomial logistic regression (MNLR). The LCA identified six different groups of airport clusters based on the implementation of noise pollution mitigation policies ranging from the likely implementation of very few policies, to the likely implementation of almost all identified policies. Those airports in Group 6, the group most likely to implement a comprehensive and wide array of noise pollution mitigation policies, were likely to implement policies targeting different areas. These included procedural policies like noise abatement procedures and engine run-up restrictions, operational policies like instituting noise decibel limits and fining aircraft for exceeding those noise limits, community programs like sound insulation and zoning restriction laws, and tracking policies through the implementation of noise monitors and flight tracking systems. Airports were more likely to implement comprehensive noise policies and belong to Group 6, than to Group 1 and not implement many policies, as population density increased, as airport hub sizes increased, and if airports were located in the West. Chapter 5 describes the conclusions that can be made from the results detailed in this chapter. A discussion will elaborate on the implications of the results and recommendations for future studies will be provided.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Chapter 4 provided a detailed analysis of the data collected to answer the two research questions. This chapter will present a summary of the study, provide a discussion of the findings, present recommendations, and suggest future research studies in the area of aircraft noise pollution mitigation.

5.1 Summary of the Study

This study aimed to understand the current landscape of potential solutions to noise pollution near airport communities at some of the busiest airports in the United States. Currently, very little research has been completed in identifying the target areas for noise pollution mitigation. Girvin (2009) and Netjasov (2012) began to identify noise policy strategies implemented around the world. Their research, however, only identified current practices around the world with a broad overview.

This research narrowed that overview down to the status of one specific country, with a specific set of airports. Using the Boeing noise and emissions database (2011), 132 Class B and Class airports in the United States were identified to have been categorized by their use, or non-use, of 20 potential noise pollution mitigation policies. Of the 20 policies that were initially examined, only one was implemented by federal law; therefore, this study only examined the use of 19 potential noise pollution mitigation policies. The policies ranged from directing aircraft around populated centers via air traffic control, or using funds to add insulate homes and schools in pre-identified noise-critical areas, to tracking and identification noise sensor systems that flag aircraft and airlines for fine when a specific noise decibel threshold is exceeded.

Based on the presence of various noise policies at the 132 airports the first research question posed was: “What are the current policy strategies utilized by large commercial airports in the United States and how frequently are they implemented?” This question was answered through coding the data based on whether or not a particular policy existed and using a latent class analysis (LCA) procedure to classify the airport into distinct categories.

The LCA was used to determine that the airports divided into 6 different clusters of policies ranging from unlikely implementation of any policy to the likely implementation of almost all potential policies. Community demographic data were then collected from the 2010 U.S. Census for a ten-mile radius of the 132 airports. These data were used to answer the second research question: “To what extent do regional and local community characteristics predict airport noise mitigation policies?” The 6 group classifications of the LCA were used as outcomes in a multinomial logistic regression (MNLR) and the community characteristics were used as independent variables. The results determined the likelihood of a particular predictor influencing an airport belonging to a particular policy group class over another. Differences existed between the groups based on the predictors.

5.2 Conclusions

The six classification groups from the LCA were distinct groups and each implemented a different set of noise mitigation policies. These groups and their potential policy implementation definitions are presented in Table 5.1. Similar policies appeared to be implemented consistently. Community policies consisted of strategies like sound insulation for homes and schools, homeowner purchase assurance, zoning laws, avigation, real estate disclosure laws, and the ability for airports to acquire land. These policies required funds or legislation that directly affected community residents.

Table 5.1

Group Classification Definitions

Group Classification	Policy Implementation Status
Group 1	Implementation Unlikely
Group 2	Implementation of some community policies somewhat likely (e.g., sound insulation)
Group 3	Implementation of noise abatement procedures and noise monitoring likely
Group 4	Implementation of noise abatement procedures and noise monitoring likely, implementation of community policies somewhat likely
Group 5	Implementation of everything likely except for airport noise level restrictions
Group 6	Implementation of nearly all policies likely

Certain policies targeted procedures for aircraft, such as noise abatement procedures, engine run-up procedures, and preferential runways. Several policies directly impacted operation for aircraft and required awareness of the aircraft operator. These included airport curfews, noise charges, auxiliary power unit restrictions, noise level limits, and operating quotas. This set of policies was only implemented consistently in Group 6 because they potentially impact the ability for aircraft to operate, possibly changing procedures that operator would typically prefer to implement without those policies in place. Many of the airports may not feel comfortable forcing airlines that supply revenue to the airport to comply with restrictive policies that add repercussions to their operations.

It seemed that region was an important factor in determining the policies a particular airport would implement. Both the map depictions of the airports classified in each policy group and the results from LCA showed indications of the importance of region. Many of the airports in Group 1 were east of the Mississippi and in the southern part of the United States. These areas were typically less densely-populated and the region was more averse to restrictions that added burdens to industry. In contrast, many of the airports in Group 6 were in more densely-populated areas in the western United States. Generally, the western portion of the United States appeared to be more favorable to environmental restrictions and were generally not averse to adding restrictions to industry for better living conditions for community residents.

It appeared that Group 6 was most different from Group 1 regarding the airport and community demographics indicating the likelihood of policy implementation. Group 1 and Group 2 were similarly contrasted to Group 5 and Group 6. Group 3 and Group 4 were in the middle of the policy clusters, with a likelihood of implementing some, but not all of the policies. They were more different from Group 1 and Group 2 than Group 5 and

Group 6. That seemed to indicate that the choice to implement any specific group of policies was more important regarding the differences in demographic makeup of the airport communities than the difference between implementing some noise policies and most noise policies.

5.3 Recommendations for Practice

Based on the results of the study there are some takeaways that may be useful for the aviation industry. Despite there being a wide range of policies airports implement to combat noise pollution, there are common policies used throughout the country. The region appears to be important in determining the types of policies that airports choose to implement so policy makers can use the classifications to help make broad policies that improve general areas. The airports in the southern portion of the United States east of the Mississippi are generally the most lenient toward aircraft noise and it may be difficult to make more stringent noise limitations there. However, many airports in the western portion of the United States are very concerned about total noise production from aircraft and invest in noise monitoring and flight tracking systems. Further restrictions limiting noise that affects an airport community may be seen more favorably. It is possible that political beliefs and beliefs about the role of government interference in industry may play a role in the types of policies an airport will implement in a certain location. However, the evidence suggests that a single approach that attempts to limit noise and accommodate all airport communities may not be as successful as a flexible approach that allows different policies in different parts of the county.

It appears to be evident from the analysis of community demographics that the people who are affected by noise from aircraft may be more marginalized members of a community who live closer to airports in more urban populations. It appears that these groups of people are more negatively impacted by aircraft noise than others as well. In some of the less stringent noise policy airports, the percentage of minorities seemed to be closer to airport boundaries than in airport groups that implemented more stringent policies. The percentage of poor people and families with kids under 18 seemed to be in a similar situation as well. They may be burdened by other external factors and airport noise may be affecting them in ways that has not been noticed yet.

In order to understand where the noise from aircraft is affecting community residents the most, and how it is affecting the residents, airports need to continue to work with the communities and the FAA through completions of the FAR Part 150 noise studies. These studies identify the distributions of noise levels on a community and pinpoint the consistently nosiest locations. From there, FAR Part 161 studies can be completed to adjust flight paths and incorporate restrictions so to reduce the disturbances on the communities.

Previous literature has indicated there are a variety of health problems associated with aircraft noise (Pepper, Nascarella, and Kendall, 2003; Collette, 2011) and because of the variations in community demographics and the variations in noise limitations at airports, certain communities may be more affected than others. This research can be used as a starting point to identify people within similar airport conditions and under aircraft paths at airports implementing similar policies.

This research should not be used as the only possible classification of airport policies and the only identification of variables impacting communities close to airports. There may be unobserved variables that impact how airports determine their noise policy strategies. There may also be other noise mitigation policies not identified by the existing research. It is necessary to continue this research to identify the best practices that reduce the harsh impacts of noise on airport communities. Aviation will be the primary transportation method for people to travel around the world. To accommodate the growing demand, aircraft will have to continue to become larger and heavier, creating more noise during phases of flight that are close to the ground. Policies only targeting noise from engine production may not have the most impact on noise reduction in the future, particularly and specifically on communities that live near airports.

Noise complaints may also be important indicators of a community that is not content with the current status of aircraft over a community. While noise may be determined to be within thresholds that should not be concerning, aircraft produce a specific noise. Any noise at all may be an intrusion to peacefulness, especially with a change in flight paths or an increase in the number of flights over a specific area. It is challenging to model noise complaints because of the repetitive calls from only a few callers. Some community members who are disturbed by the noise may be wary of calling and making a complaint because they are aware that someone else calls continuously about the aircraft. There may be a difference in the number of calls depending on the noise policies in place at a particular airport.

It is important for airport leaders and policy makers concerned with the noise pollution around airport communities take steps to understand the landscapes and environments they are working within. This research has provided a foundation of the overall airport noise mitigation policy landscape around the Class B and Class C airports in the United States. The most important consideration is that noise production concerns are not 100 percent solved and, if all predictions remain correct, will become a more serious problem in the future. Before specific beneficial policies can be targeted there needs to be an understanding of what is already in place and what airports are already doing to combat noise.

5.4 Future Research Recommendations

The results of this study provided answers to the two specific research questions, however, it also created the potential for related research to be conducted in the future. This study attempts to address the current status of noise policy mitigation strategies at the Class B and Class C airport in the United States. It does not attempt to determine whether a potential policy is the correct policy that should be implemented, or provide a specific direction an airport should take regarding the implementation of policies in the future. More data will be required to address those questions not available to the researcher in this particular study. A few areas that need to be addressed through future research are given below.

1. This research only addressed the current status of the airports at Class B and Class C airports in the United States. Many smaller airports are becoming increasing busier to general aviation jets. Long Beach airport in Los Angeles is a Class D airport and outside of the scope of this study. However, they have

a noise monitoring program that fines aircraft for excessive noise production. Are airports generally associated with General Aviation able to be classified into noise policy groups?

2. Another area this study does not address is the status of noise policies outside the United States. Noise pollution on airport communities is not limited to the United States and the growth in the industry is expected worldwide. What noise policies do airport implement in other parts of the world?
3. This study examines the policies in existence specifically at airports in the United States. There have been some federal regulations that have targeted noise production in an effort to minimize the effect of noise on communities. How has the United States Congress reacted to community concerns about aviation noise pollution and to what extent have federal agencies engaged with Congress to set federal noise mitigation policies?
4. How do community demographics (e.g. home values, rates of poverty, household size) change as distances get farther from airport centers? This research only looked at the ten-mile radius around airports, but are there differences in community demographics at different intervals?
5. Are there certain noise policies that are believed to be more beneficial and have a greater impact on reducing noise than other policies? Do airport leaders and community citizens have different opinions about noise concerns?
6. Are there differences in noise complaints from the communities that depend on the particular noise mitigation policies in place at airports?

7. What political factors might account for differences in airport noise mitigation policies? The demographic data suggests that distance from an airport, the density of the population around an airport, and socioeconomic factors may be important, but the extent to which these groups mobilize and force change in their communities needs to be examined further.

5.5 Summary

This chapter has provided the conclusions from this study based on the findings and analyses presented in Chapter 4. The results of the study highlight the current lack of organization among industry leaders on the specific problem of combatting noise pollution in the surrounding airport communities. There are clear lines about how certain airports choose to implement certain policies, and there are similarities among airports on how they approach the problem, particularly among region of the airport and the population the airport serves. This study provides the first step toward understanding what is being done to combat noise pollution and provides a platform for those who wish to study this problem further. A point of emphasis is on the expected growth of the aviation community in terms of the overall numbers of aircraft in the sky at one time, as well as the expected growth in the overall number of traveling public on aircraft. To address this problem, this study provides recommendations to better understand this issue as well as recommendations for future studies.

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APPENDICES

Appendix A: Study Airports by Name Identification and Location

Table A 1

Study Airports Identification and Location Information

Airport ID	Name	City	State
ABE	Lehigh Valley International Airport	Allentown	Pennsylvania
ABQ	Albuquerque International Sunport	Albuquerque	New Mexico
ACY	Atlantic City International Airport	Atlantic City	New Jersey
ALB	Albany International Airport	Albany	New York
ANC	Ted Stevens Anchorage International Airport	Anchorage	Alaska
ATL	Hartsfield-Jackson Atlanta International Airport	Atlanta	Georgia
AUS	Austin-Bergstrom International Airport	Austin	Texas
AVL	Asheville Regional Airport	Asheville	North Carolina
BDL	Bradley International Airport	Hartford	Connecticut
BGR	Bangor International Airport	Bangor	Maine
BHM	Birmingham International Airport	Birmingham	Alabama
BIL	Billings Logan International Airport	Billings	Montana
BNA	Nashville International Airport	Nashville	Tennessee
BOI	Boise Air Terminal	Boise	Idaho
BOS	Logan International Airport	Boston	Massachusetts
BTR	Baton Rouge Metropolitan Airport	Baton Rouge	Louisiana
BTV	Burlington International Airport	Burlington	Vermont
BUF	Buffalo Niagara International Airport	Buffalo	New York
BUR	Bob Hope Airport	Burbank	California
BWI	Baltimore/Washington International Airport	Baltimore	Maryland
CAE	Columbia Metropolitan Airport	Columbia	South Carolina

Table A 1 continued

Airport ID	Name	City	State
CAK	Akron-Canton Regional Airport	Akron	Ohio
CHA	Lovell Field Airport	Chattanooga	Tennessee
CHS	Charleston Air Force Base/International Airport	Charleston	South Carolina
CID	The Eastern Iowa Airport	Cedar Rapids	Iowa
CLE	Cleveland-Hopkins International Airport	Cleveland	Ohio
CLT	Charlotte/Douglas International Airport	Charlotte	North Carolina
CMH	Port Columbus International Airport	Columbus	Ohio
CMI	University of Illinois-Willard Airport	Champaign	Illinois
COS	Colorado Springs Municipal Airport	Colorado Springs	Colorado
CRP	Corpus Christi International Airport	Corpus Christi	Texas
CRW	Yeager Airport	Charleston	West Virginia
CVG	Cincinnati International Airport	Covington	Kentucky
DAB	Daytona Beach International Airport	Daytona Beach	Florida
DAL	Dallas Love Field Airport	Dallas	Texas
DCA	Washington National Airport	Washington D.C.	Washington D.C.
DEN	Denver International Airport	Denver	Colorado
DFW	Dallas/Fort Worth International Airport	Dallas	Texas
DSM	Des Moines International Airport	Des Moines	Iowa
DTW	Detroit Metropolitan Wayne County Airport	Detroit	Michigan
ELP	El Paso International Airport	El Paso	Texas
EVV	Evansville Regional Airport	Evansville	Indiana
EWR	Newark Liberty International Airport	Newark	New Jersey
FAT	Fresno Yosemite International Airport	Fresno	California
FAY	Fayetteville Regional Airport	Fayetteville	North Carolina
FLL	Fort Lauderdale International Airport	Fort Lauderdale	Florida

Table A 1 continued

Airport ID	Name	City	State
FWA	Fort Wayne International Airport	Fort Wayne	Indiana
GEG	Spokane International Airport	Spokane	Washington
GRB	Austin-Straubel International Airport	Green Bay	Wisconsin
GRR	Gerald R Ford International Airport	Grand Rapids	Michigan
GSO	Piedmont Triad International Airport	Greensboro	North Carolina
GSP	Greenville Spartanburg International Airport	Greenville	South Carolina
HNL	Honolulu International Airport	Honolulu	Hawaii
HOU	William P Hobby Airport	Houston	Texas
HRL	Valley International Airport	Harlingen	Texas
HSV	Huntsville International Airport	Huntsville	Alabama
IAD	Washington Dulles International Airport	D.C.	D.C.
IAH	George Bush Intercontinental Airport	Houston	Texas
ICT	Wichita Eisenhower National Airport	Wichita	Kansas
IND	Indianapolis International Airport	Indianapolis	Indiana
ISP	Long Island MacArthur Airport	Long Island	New York
JAN	Jackson International Airport	Jackson	Mississippi
JAX	Jacksonville International Airport	Jacksonville	Florida
JFK	John F Kennedy International Airport	New York	New York
LAN	Capital Region International Airport	Lansing	Michigan
LAS	McCarran International Airport	Las Vegas	Nevada
LAX	Los Angeles International Airport	Los Angeles	California
LBB	Lubbock Preston Smith International Airport	Lubbock	Texas
LFT	Lafayette Regional Airport	Lafayette	Louisiana
LGA	LaGuardia Airport	New York	New York
LIT	Bill and Hillary Clinton National Airport	Little Rock	Arkansas

Table A 1 continued

Airport ID	Name	City	State
LNK	Lincoln Airport	Lincoln	Nebraska
MCI	Kansas City International Airport	Kansas City	Missouri
MCO	Orlando International Airport	Orlando	Florida
MDW	Chicago Midway International Airport	Chicago	Illinois
MEM	Memphis International Airport	Memphis	Tennessee
MHT	Manchester Airport	Manchester	New Hampshire
MIA	Miami International Airport	Miami	Florida
MKE	General Mitchell International Airport	Milwaukee	Wisconsin
MLI	Quad City International Airport	Moline	Illinois
MOB	Mobile Regional Airport	Mobile	Alabama
MRY	Monterey Regional Airport	Monterey	California
MSN	Dane County Regional Airport	Madison	Wisconsin
MSP	Minneapolis-St Paul International	Minneapolis	Minnesota
MSY	New Orleans International Airport	New Orleans	Louisiana
MYR	Myrtle Beach International Airport	Myrtle Beach	South Carolina
OAK	Metropolitan Oakland International Airport	Oakland	California
OGG	Kahului Airport	Kahului	Hawaii
OKC	Will Rogers World Airport	Oklahoma City	Oklahoma
OMA	Eppley Airfield	Omaha	Nebraska
ONT	Ontario International Airport	Ontario	California
ORD	Chicago O'Hare International Airport	Chicago	Illinois
ORF	Norfolk International Airport	Norfolk	Virginia
PBI	Palm Beach International Airport	Palm Beach	Florida
PDX	Portland International Airport	Portland	Oregon
PHL	Philadelphia International Airport	Philadelphia	Pennsylvania

Table A 1 continued

Airport ID	Name	City	State
PHX	Phoenix Sky Harbor International Airport	Phoenix	Arizona
PIT	Pittsburgh International Airport	Pittsburgh	Pennsylvania
PNS	Pensacola International Airport	Pensacola	Florida
PVD	Theodore Francis Green State Airport	Providence	Rhode Island
PWM	Portland International Jetport	Portland	Maine
RDU	Raleigh-Durham International Airport	Raleigh	North Carolina
RIC	Richmond International Airport	Richmond	Virginia
RNO	Reno/Tahoe International Airport	Reno	Nevada
ROA	Roanoke Regional Airport	Roanoke	Virginia
ROC	Greater Rochester International Airport	Rochester	New York
RSW	Southwest Florida International Airport	Fort Myers	Florida
SAN	San Diego International Airport	San Diego	California
SAT	San Antonio International Airport	San Antonio	Texas
SAV	Savannah/Hilton Head International Airport	Savannah	Georgia
SBA	Santa Barbara Municipal Airport	Santa Barbara	California
SBN	South Bend International Airport	South Bend	Indiana
SDF	Louisville International Airport	Louisville	Kentucky
SEA	Seattle/Tacoma International Airport	Seattle	Washington
SFB	Orlando Sanford International Airport	Orlando	Florida
SFO	San Francisco International Airport	San Francisco	California
SGF	Springfield-Branson National Airport	Springfield	Missouri
SHV	Shreveport Regional Airport	Shreveport	Louisiana
SJC	San Jose International Airport	San Jose	California
SLC	Salt Lake City International Airport	Salt Lake City	Utah
SMF	Sacramento International Airport	Sacramento	California

Table A 1 continued

Airport ID	Name	City	State
SNA	John Wayne-Orange County Airport	Santa Ana	California
SPI	Abraham Lincoln Capital Airport	Springfield	Illinois
SRQ	Sarasota/Bradenton International Airport	Sarasota	Florida
STL	St Louis International Airport	St. Louis	Missouri
SYR	Syracuse Hancock International Airport	Syracuse	New York
TLH	Tallahassee International Airport	Tallahassee	Florida
TOL	Toledo Express Airport	Toledo	Ohio
TPA	Tampa International Airport	Tampa	Florida
TUL	Tulsa International Airport	Tulsa	Oklahoma
TUS	Tucson International Airport	Tucson	Arizona
TYS	McGhee Tyson Airport	Knoxville	Tennessee

Appendix B: Additional Airport Information

Table B 1

Additional Airport Information

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
ABE	40.6522	75.4403	C	4	4	0.21
ABQ	35.0403	106.6092	C	4	9	0.47
ACY	39.4575	74.5772	C	6	12	0.63
ALB	42.7492	73.8019	C	6	11	0.58
ANC	61.1744	149.9964	C	6	5	0.26
ATL	33.6367	84.4281	B	6	11	0.58
AUS	30.1944	97.6700	C	4	6	0.32
AVL	35.4361	82.5417	C	6	9	0.47
BDL	41.9389	72.6833	C	1	8	0.42
BGR	44.8075	68.8281	C	6	11	0.58
BHM	33.5639	86.7522	C	5	10	0.53
BIL	45.8078	108.5428	C	5	12	0.63
BNA	36.1244	86.6783	C	1	12	0.63
BOI	43.5644	116.2228	C	5	5	0.26
BOS	42.3631	71.0064	B	3	7	0.37
BTR	30.5328	91.1500	C	1	8	0.42
BTV	44.4719	73.1533	C	5	14	0.74
BUF	42.9406	78.7322	C	1	12	0.63
BUR	34.2006	118.3586	C	2	13	0.68
BWI	39.1753	76.6683	B	1	13	0.68
CAE	33.9389	81.1194	C	6	3	0.16

Table B 1 continued

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
CAK	40.9161	81.4422	C	6	12	0.63
CHA	35.0353	85.2036	C	6	9	0.47
CHS	32.8986	80.0406	C	6	8	0.42
CID	41.8847	91.7108	C	6	13	0.68
CLE	41.4094	81.8550	B	1	5	0.26
CLT	35.2139	80.9431	B	3	8	0.42
CMH	39.9981	82.8919	C	3	10	0.53
CMI	40.0389	88.2778	C	6	13	0.68
COS	38.8058	104.7008	C	5	9	0.47
CRP	27.7704	97.5011	C	5	14	0.74
CRW	38.3731	81.5933	C	5	12	0.63
CVG	39.0489	84.6678	B	1	14	0.74
DAB	29.1800	81.0581	C	5	11	0.58
DAL	32.8472	96.8517	B	3	11	0.58
DCA	38.8522	77.0378	B	3	9	0.47
DEN	39.8617	104.6731	B	3	8	0.42
DFW	32.8969	97.0381	B	1	8	0.42
DSM	41.5339	93.6631	C	6	2	0.11
DTW	42.2125	83.3533	B	1	3	0.16
ELP	31.8072	106.3775	C	6	4	0.21
EVV	38.0369	87.5322	C	6	10	0.53
EWR	40.6925	74.1686	B	2	2	0.11
FAT	36.7761	119.7181	C	1	11	0.58
FAY	34.9911	78.8803	C	5	1	0.05
FLL	26.0726	80.1528	C	3	4	0.21

Table B 1 continued

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
FWA	40.9783	85.1953	C	5	5	0.26
GEG	47.6200	117.5339	C	5	13	0.68
GRB	44.4847	88.1297	C	6	7	0.37
GRR	42.8808	85.5228	C	5	8	0.42
GSO	36.0978	79.9372	C	6	4	0.21
GSP	34.8956	82.2189	C	5	10	0.53
HNL	21.3187	157.9225	B	1	13	0.68
HOU	29.6456	95.2789	B	5	3	0.16
HRL	26.2285	97.6544	C	6	2	0.11
HSV	34.6372	86.7750	C	6	0	0.00
IAD	38.9475	77.4600	B	5	1	0.05
IAH	29.9844	95.3414	B	5	3	0.16
ICT	37.6500	97.4331	C	6	5	0.26
IND	39.7172	86.2947	C	1	3	0.16
ISP	40.7953	73.1003	C	6	6	0.32
JAN	32.3111	90.0758	C	6	3	0.16
JAX	30.4942	81.6878	C	6	3	0.16
JFK	40.6397	73.7789	B	2	5	0.26
LAN	42.7786	84.5867	C	6	3	0.16
LAS	36.0800	115.1522	B	1	2	0.11
LAX	33.9425	118.4072	B	1	2	0.11
LBB	33.6636	101.8228	C	6	10	0.53
LFT	30.2053	91.9875	C	6	3	0.16
LGA	40.7772	73.8725	B	2	6	0.32
LIT	34.7294	92.2244	C	6	7	0.37

Table B 1 continued

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
LNK	40.8511	96.7592	C	5	5	0.26
MCI	39.2975	94.7139	B	6	3	0.16
MCO	28.4294	81.3089	B	1	8	0.42
MDW	41.7861	87.7525	C	3	2	0.11
MEM	35.0425	89.9767	B	5	6	0.32
MHT	42.9328	71.4358	C	1	1	0.05
MIA	25.7933	80.2906	B	4	8	0.42
MKE	42.9472	87.8967	C	1	1	0.05
MLI	41.4486	90.5072	C	5	12	0.63
MOB	30.6914	88.2428	C	5	3	0.16
MRY	36.5869	121.8431	C	4	1	0.05
MSN	43.1397	89.3375	C	5	1	0.05
MSP	44.8819	93.2217	B	1	3	0.16
MSY	29.9933	90.2581	B	3	5	0.26
MYR	33.6797	78.9283	C	6	0	0.00
OAK	37.7214	122.2208	C	2	3	0.16
OGG	20.8986	156.4306	C	4	4	0.21
OKC	35.3931	97.6008	C	5	7	0.37
OMA	41.3031	95.8942	C	6	11	0.58
ONT	34.0561	117.6011	C	1	11	0.58
ORD	41.9808	87.9067	B	4	5	0.26
ORF	36.8947	76.2011	C	6	8	0.42
PBI	26.6832	80.0956	C	3	9	0.47
PDX	45.5883	122.5975	C	4	9	0.47
PHL	39.8722	75.2408	B	4	10	0.53

Table B 1 continued

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
PHX	33.4342	112.0117	B	1	12	0.63
PIT	40.4914	80.2328	B	1	8	0.42
PNS	30.4733	87.1867	C	6	7	0.37
PVD	41.7239	71.4283	C	4	3	0.16
PWM	43.6461	70.3092	C	4	10	0.53
RDU	35.8778	78.7875	C	2	3	0.16
RIC	37.5053	77.3197	C	6	8	0.42
RNO	39.4992	119.7681	C	4	11	0.58
ROA	37.3256	79.9756	C	5	4	0.21
ROC	43.1189	77.6725	C	6	8	0.42
RSW	26.5362	81.7553	C	5	10	0.53
SAN	32.7336	117.1897	B	2	13	0.68
SAT	29.5336	98.4697	C	4	4	0.21
SAV	32.1275	81.2022	C	6	9	0.47
SBA	34.4261	119.8414	C	1	7	0.37
SBN	41.7083	86.3172	C	5	4	0.21
SDF	38.1742	85.7364	C	1	9	0.47
SEA	47.4500	122.3117	B	2	8	0.42
SFB	28.7767	81.2356	C	6	1	0.05
SFO	37.6189	122.3750	B	2	13	0.68
SGF	37.2456	93.3886	C	5	7	0.37
SHV	32.4467	93.8256	C	6	12	0.63
SJC	37.3628	121.9292	C	3	1	0.05
SLC	40.7883	111.9778	B	1	3	0.16
SMF	38.6956	121.5908	C	1	12	0.63

Table B 1 continued

Airport ID	Latitude	Longitude	Airspace	Policy Group	Noise Policies Used	Percent Implementation
SNA	33.6756	117.8683	C	2	8	0.42
SPI	39.8442	89.6781	C	6	12	0.63
SRQ	27.3954	82.5544	C	2	17	0.89
STL	38.7486	90.3700	B	4	3	0.16
SYR	43.1111	76.1064	C	5	15	0.79
TLH	30.3967	84.3503	C	5	7	0.37
TOL	41.5867	83.8078	C	1	7	0.37
TPA	27.9756	82.5333	B	4	10	0.53
TUL	36.1983	95.8881	C	1	8	0.42
TUS	32.1161	110.9411	C	1	10	0.53
TYS	35.8111	83.9939	C	6	1	0.05

Appendix C: Maps of Airports by Individual Noise Policy

a. Noise Abatement Procedures

b. Engine Run Up Restrictions

c. Preferential Runway Procedures

d. Auxiliary Power Unit Restrictions

Figure C 1 Procedural noise mitigation policies. Maps of airports implementing noise mitigation policies that require procedural compliance by pilots either through regulatory compliance with procedures (e.g. noise abatement procedures) or an understanding of airport practices (e.g. engine run-up procedures).

a. Operating Quotas

b. Charges and Fines for Noise

c. Noise Level Limits

d. Noise Budget Limitations

Figure C 2 Operational noise mitigation policies. Maps of airports implementing noise mitigation policies that require operational compliance by airline or owner either through limitations placed on the ability to operate aircraft (e.g. quotas on the total number of aircraft allowed at an airport) or standard operating procedure checklist to not incur a burden (e.g. fines for exceeding noise sensor limitation).

a. Ability to Acquire Land

b. Avigation

c. Homeowner Purchase Assurance

d. Noise Contour Maps

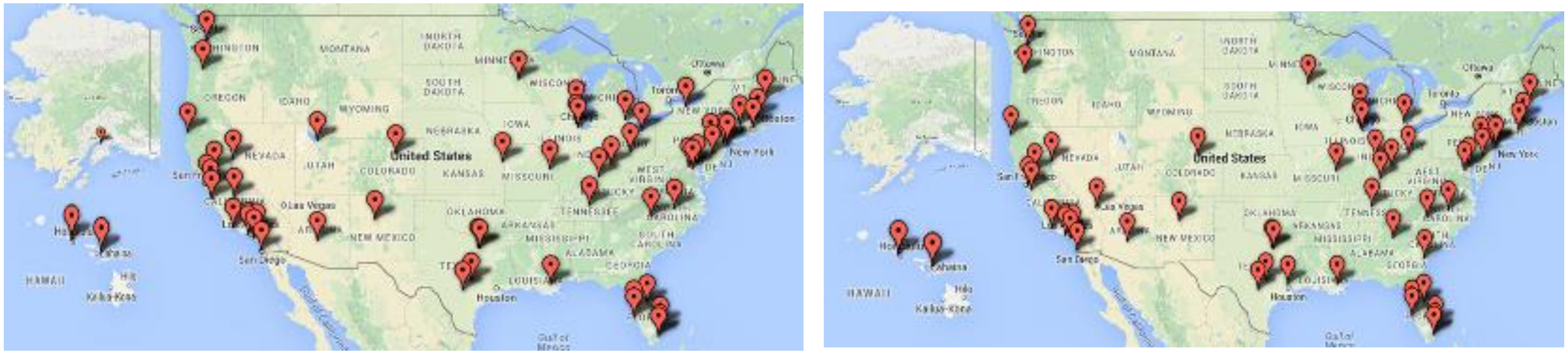
e. Populations within Contours Identified

f. Real Estate Disclosure Laws

g. Sound Insulation Programs

h. Zoning Laws

Figure C 3 Community noise mitigation policies. Maps of airports (a-h) implementing noise mitigation policies involving the surrounding community. These policies require airports to understand how they affect the community and spend money to combat noise pollution through programs such as sound proofing residential homes and programs (g) or increasing awareness through laws such as zoning restrictions (h).



a. Noise Monitoring Systems

b. Flight Tracking Systems

Figure C 4 Sensors and tracking noise mitigation policies. Maps of airports (a-b) implementing noise mitigation policies involving noise sensors installed in the community. These policies require airports purchase systems that can either just record noise production levels in decibels (monitoring systems) or identify specific aircraft overhead in addition to recording noise levels (flight tracking).

Appendix D: Multinomial Logistic Regression Results by Reference Group

Table D 1

Multinomial Logistic Regression with Group 1 as Reference (N = 132)

	GROUP 2[1]					GROUP 3[1]					GROUP 4[1]				
	b	se	*p*	OR		b	se	*p*	OR		b	se	*p*	OR	
Population[a]	0.40	0.47		0.59	3.76	1.43	0.49	**	1.58	10.97	0.97	0.46	*	1.08	6.48
White[b]	0.62	0.37	+	0.91	3.81	0.05	0.62		0.31	3.55	-0.09	0.49		0.35	2.40
Kids[c]	3.49	2.15		0.48	>1000	1.04	2.70		0.01	561.60	-1.84	2.51		0.00	21.56
Household[d]	-5.50	4.48		0.00	26.87	-6.20	6.52		0.00	715.71	-1.47	5.55		0.00	>1000
Poor[e]	2.47	1.27	+	0.98	142.19	0.81	2.04		0.04	122.26	0.79	1.59		0.10	49.85
Home Value[f]	0.03	0.07		0.91	1.17	0.06	0.08		0.91	1.24	0.03	0.07		0.90	1.18
Public Asst[g]	-2.48	2.59		0.00	13.43	-11.69	6.20	+	0.00	1.59	-5.63	4.15		0.00	12.24
Midwest[2]	-0.72	0.84		0.09	2.55	0.63	1.71		0.07	52.95	0.97	1.41		0.17	41.45
Northeast[2]	0.13	1.12		0.13	10.33	1.05	2.39		0.03	311.24	3.31	1.53	*	1.35	553.80
West[2]	1.93	1.52		0.35	133.87	4.15	2.18	+	0.89	>1000	5.03	1.89	**	3.79	>1000
Airport Hub	0.86	0.86		0.44	12.69	17.22	>1000		0.00	>1000	2.56	1.08	*	1.54	108.02
International	-0.19	0.59		0.26	2.66	1.14	1.62		0.13	74.60	0.71	1.11		0.23	17.69
Constant	-5.28	8.34				-8.57	1065.62				3.36	12.97			

Note. [1]Group 1 is the reference group. LR $Chi^2(60) = 162.02$. [2]South region is the reference group

$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo $R^2 = .37$

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 1 continued

	GROUP 5[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	0.99	0.44	*	1.14	6.29	1.81	0.52	***	2.21	16.73
White[b]	0.58	0.44		0.76	4.20	0.64	0.68		0.50	7.12
Kids[c]	-1.48	2.16		0.00	>1000	-1.93	2.83		0.00	>1000
Household[d]	3.16	4.75		0.00	>1000	-2.17	7.06		0.00	>1000
Poor[e]	1.73	1.41		0.00	>1000	-1.64	2.43		0.00	>1000
Home Value[f]	0.04	0.07		0.91	1.18	0.03	0.08		0.89	1.20
Public Asst[g]	-3.39	3.30		0.00	21.65	-10.08	6.43		0.00	12.49
Midwest[2]	0.81	1.15		0.24	21.52	-14.07	914.06		0.00	>1000
Northeast[2]	2.03	1.34		0.56	104.82	-0.23	2.51		0.01	109.25
West[2]	4.20	1.69	*	2.44	>1000	5.78	2.53	*	2.26	>1000
Airport Hub	2.65	0.91	**	2.37	84.83	3.83	1.83	*	1.28	>1000
International	1.18	0.92		0.53	19.83	0.39	1.72		0.05	42.80
Constant	-14.85	10.58				2.7	18.00			

Note. [1]Group 1 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^+p < .10$. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 2

Multinomial Logistic Regression with Group 2 as Reference (N = 132)

	GROUP 1[1]					GROUP 3[1]					GROUP 4[1]				
	b	se	*p*		OR	b	se	*p*		OR	b	se	*p*		OR
Population[a]	-0.40	0.47		0.27	1.69	1.02	0.52		1.00	7.76	0.57	0.49		0.68	4.62
White[b]	-0.62	0.37	+	0.26	1.10	-0.57	0.64		0.16	1.97	-0.71	0.52		0.18	1.35
Kids[c]	-3.49	2.15		0.00	2.07	-2.45	2.92		0.00	26.62	-5.33	2.79		0.00	1.14
Household[d]	5.50	4.48		0.04	>1000	-0.70	6.91		0.00	>1000	4.03	6.08		0.00	>1000
Poor[e]	-2.47	1.27	+	0.01	1.02	-1.65	2.10		0.00	11.78	-1.67	1.68		0.01	5.06
Home Value[f]	-0.03	0.07		0.85	1.10	0.03	0.07		0.89	1.19	0.00	0.07		0.88	1.14
Public Asst[g]	2.48	2.59		0.07	>1000	-9.21	6.20		0.00	18.88	-3.15	4.16		0.00	149.08
Midwest[2]	0.72	0.84		0.39	10.69	1.34	1.73		0.13	113.49	1.69	1.44		0.32	90.27
Northeast[2]	-0.13	1.12		0.10	7.94	0.92	2.43		0.02	293.80	3.18	1.60	*	1.05	550.87
West[2]	-1.93	1.52		0.01	2.84	2.22	1.92		0.21	401.46	3.10	1.59	+	0.98	504.48
Airport Hub	-0.86	0.86		0.08	2.29	16.37	>1000		0.00	>1000	1.70	1.12		0.61	49.08
International	0.19	0.59		0.38	3.85	1.32	1.62		0.16	89.49	0.89	1.11		0.27	21.68
Constant	5.28	8.34				-3.29	1065.62				8.64	13.40			

Note. [1]Group 2 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.
Pseudo $R^2 = .37$
Log Likelihood = -140.66
[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 2 continued

	GROUP 5[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	0.59	0.47		0.72	4.50	1.40	0.54		1.41	11.79
White[b]	-0.04	0.46		0.39	2.36	0.02	0.69		0.26	3.94
Kids[c]	-4.97	2.48		0.00	0.89	-5.42	3.05		0.00	1.74
Household[d]	8.66	5.36		0.16	>1000	3.33	7.42		0.00	>1000
Poor[e]	-0.74	1.51		0.03	9.16	-4.11	2.50		0.00	2.19
Home Value[f]	0.01	0.06		0.89	1.14	0.00	0.07		0.87	1.16
Public Asst[g]	-0.90	3.28		0.00	248.36	-7.60	6.41		0.00	144.08
Midwest[2]	1.53	1.19		0.45	47.06	-13.35	914.06		0.00	>1000
Northeast[2]	1.90	1.40		0.43	104.64	-0.36	2.55		0.00	102.79
West[2]	2.27	1.35	+	0.68	138.31	3.85	2.30	+	0.52	>1000
Airport Hub	1.80	0.94	+	0.95	38.36	2.98	1.85		0.52	736.41
International	1.37	0.93		0.63	24.35	0.58	1.71		0.06	51.22
Constant	-9.58	11.03				7.98	18.22			

Note. [1]Group 2 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 3

Multinomial Logistics Regression with Group 3 as Reference (N = 132)

	GROUP 1[1]					GROUP 2[1]					GROUP 4[1]				
	b	se	*p*	OR		b	se	*p*	OR		b	se	*p*	OR	
Population[a]	-1.43	0.49	**	0.09	0.63	-1.02	0.52		0.13	1.00	-0.45	0.31		0.35	1.16
White[b]	-0.05	0.62		0.28	3.23	0.57	0.64		0.51	6.20	-0.14	0.55		0.30	2.55
Kids[c]	-1.04	2.70		0.00	70.13	2.45	2.92		0.04	>1000	-2.88	2.61		0.00	9.38
Household[d]	-0.81	2.04		0.00	>1000	1.65	2.10		0.00	>1000	-0.02	1.76		0.00	>1000
Poor[e]	-0.06	0.08		0.01	23.99	-0.03	0.07		0.08	321.13	-0.03	0.06		0.03	30.97
Home Value[f]	11.69	6.20		0.81	1.10	9.21	6.20		0.84	1.12	6.06	5.89		0.86	1.10
Public Asst[g]	116.90	62.00	+	0.63	>1000	92.10	61.98		0.05	>1000	60.57	58.93		0.00	>1000
Midwest[2]	-0.63	1.71		0.02	15.12	-1.34	1.73		0.01	7.73	0.34	1.66		0.05	36.35
Northeast[2]	-1.05	2.39		0.00	37.80	-0.92	2.43		0.00	46.41	2.26	2.25		0.11	792.27
West[2]	-4.15	2.18	+	0.00	1.12	-2.22	1.92		0.00	4.70	0.88	1.71		0.08	68.33
Airport Hub	-17.22	>1000		0.00	>1000	-16.37	>1000		0.00	>1000	-14.66	>1000		0.00	>1000
International	-1.14	1.62		0.01	7.70	-1.32	1.63		0.01	6.37	-0.43	1.63		0.03	15.93
Constant	8.57	1065.62				3.29	1065.62				11.93	1065.61			

Note. [1]Group 3 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.
Pseudo $R^2 = .37$
Log Likelihood = -140.66
[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 3 continued

	GROUP 5[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	-0.44	0.30		0.36	1.16	0.38	0.31		0.80	2.69
White[b]	0.53	0.53		0.60	4.83	0.59	0.68		0.48	6.83
Kids[c]	-2.52	2.42		0.00	9.25	-2.97	2.75		0.00	11.18
Household[d]	0.92	1.68		0.14	>1000	-2.46	2.33		0.00	>1000
Poor[e]	-0.02	0.06		0.09	67.68	-0.03	0.06		0.00	8.26
Home Value[f]	8.31	5.63		0.87	1.10	1.61	7.25		0.86	1.10
Public Asst[g]	83.05	56.29		0.07	>1000	16.08	72.51		0.00	>1000
Midwest[2]	0.18	1.54		0.06	24.45	-14.70	914.06		0.00	>1000
Northeast[2]	0.98	2.21		0.03	204.42	-1.28	2.56		0.00	41.90
West[2]	0.05	1.68		0.04	28.24	1.63	2.36		0.05	516.46
Airport Hub	-14.57	>1000		0.00	>1000	-13.39	>1000		0.00	>1000
International	0.04	1.58		0.05	23.03	-0.74	1.89		0.01	19.35
Constant	-6.28	1065.60				11.28	1065.65			

Note. [1]Group 3 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 4

Multinomial Logistics Regression with Group 4 as Reference (N = 132)

	GROUP 1[1]					GROUP 2[1]					GROUP 3[1]				
	b	se	*p*	OR		b	se	*p*	OR		b	se	*p*	OR	
Population[a]	-0.97	0.46	*	0.15	0.93	-0.57	0.49		0.22	1.47	0.45	0.31		0.86	2.86
White[b]	0.09	0.49		0.42	2.89	0.71	0.52	+	0.74	5.63	0.14	0.55		0.39	3.37
Kids[c]	1.84	2.51		0.05	853.43	5.33	2.79		0.88	>1000	2.88	2.61		0.11	>1000
Household[d]	1.47	5.55		0.00	>1000	-4.03	6.08		0.00	>1000	-4.73	6.02		0.00	>1000
Poor[e]	-0.79	1.59		0.02	10.18	1.67	1.68		0.20	143.49	0.02	1.76		0.03	32.23
Home Value[f]	-0.03	0.07		0.85	1.11	0.00	0.07		0.88	1.14	0.03	0.06		0.91	1.16
Public Asst[g]	5.63	4.15		0.08	>1000	3.15	4.16		0.01	>1000	-6.06	5.89		0.00	242.96
Midwest[2]	-0.97	1.41		0.02	5.96	-1.69	1.44		0.01	3.09	-0.34	1.66		0.03	18.30
Northeast[2]	-3.31	1.53	*	0.00	0.74	-3.18	1.60		0.00	0.96	-2.26	2.25		0.00	8.70
West[2]	-5.03	1.89	**	0.00	0.26	-3.10	1.59	*	0.00	1.02	-0.88	1.71		0.01	11.81
Airport Hub	-2.56	1.08	*	0.01	0.65	-1.70	1.12	+	0.02	1.63	14.66	>1000		0.00	>1000
International	-0.71	1.11		0.06	4.31	-0.89	1.11		0.05	3.65	0.43	1.63		0.06	37.63
Constant	-3.36	12.97				-8.64	13.40				-11.93	1065.61			

Note. [1]Group 4 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group

$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R^2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 4 continued

	GROUP 5[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	0.01	0.25		0.62	1.65	0.83	0.34	*	1.18	4.47
White[b]	0.67	0.40	+	0.89	4.30	0.73	0.61		0.63	6.84
Kids[c]	0.36	2.19		0.02	104.45	-0.09	2.70		0.00	179.83
Household[d]	4.63	4.79		0.01	>1000	-0.70	6.71		0.00	>1000
Poor[e]	0.94	1.15		0.27	24.45	-2.44	2.15		0.00	5.97
Home Value[f]	0.01	0.05		0.92	1.10	0.00	0.06		0.89	1.12
Public Asst[g]	2.25	3.35		0.01	>1000	-4.45	6.17		0.00	>1000
Midwest[2]	-0.16	1.28		0.07	10.55	-15.04	914.06		0.00	>1000
Northeast[2]	-1.28	1.35		0.02	3.96	-3.54	2.41		0.00	3.29
West[2]	-0.83	1.31		0.03	5.74	0.75	2.20		0.03	157.73
Airport Hub	0.10	0.97		0.17	7.30	1.28	1.82		0.10	127.09
International	0.47	1.10		0.19	13.94	-0.31	1.73		0.02	21.63
Constant	-18.21	11.15				-0.66	17.14			

Note. [1]Group 4 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 5

Multinomial Logistic Regression with Group 5 as Reference (N = 132)

	GROUP 1[1]					GROUP 2[1]					GROUP 3[1]				
	b	se	*p*	OR		b	se	*p*	OR		b	se	*p*	OR	
Population[a]	-0.99	0.44	*	0.16	0.87	-0.59	0.44		0.22	1.39	0.44	0.30		0.86	2.79
White[b]	-0.58	0.44		0.24	1.32	0.04	0.44		0.42	2.56	-0.53	0.53		0.21	1.66
Kids[c]	1.48	2.16		0.06	304.46	4.97	2.16	*	1.12	>1000	2.52	2.42		0.11	>1000
Household[d]	-3.16	4.75		0.00	465.01	-8.66	4.75		0.00	6.29	-9.36	5.78		0.00	7.18
Poor[e]	-1.73	1.41		0.01	2.82	0.74	1.41		0.11	39.88	-0.92	1.68		0.01	10.81
Home Value[f]	-0.04	0.07		0.85	1.10	-0.01	0.07		0.88	1.12	0.02	0.06		0.91	1.15
Public Asst[g]	3.39	3.30		0.05	>1000	0.90	3.28		0.00	>1000	-8.31	5.63		0.00	15.31
Midwest[2]	-0.81	1.15		0.05	4.25	-1.53	1.19		0.02	2.21	-0.18	1.54		0.04	16.90
Northeast[2]	-2.03	1.34		0.01	1.80	-1.90	1.40		0.01	2.33	-0.98	2.21		0.00	28.86
West[2]	-4.20	1.69	*	0.00	0.41	-2.27	1.35	+	0.01	1.46	-0.05	1.68		0.04	25.49
Airport Hub	-2.65	0.91	**	0.01	0.42	-1.80	0.94	+	0.03	1.06	14.57	>1000		0.00	>1000
International	-1.18	0.92		0.05	1.87	-1.37	0.93		0.04	1.59	-0.04	1.58		0.04	21.08
Constant	14.85	10.58				9.58	11.03				6.28	1065.60			

Note. [1]Group 5 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^+p < .10$. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.
Pseudo $R^2 = .37$
Log Likelihood = -140.66
[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 5 continued

	GROUP 4[1]					GROUP 6[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	-0.01	0.25		0.61	1.60	0.82	0.47	*	1.18	4.35
White[b]	-0.67	0.40	+	0.23	1.12	0.06	0.37		0.34	3.31
Kids[c]	-0.36	2.19		0.01	50.92	-0.45	2.15		0.00	98.16
Household[d]	-4.63	4.79		0.00	117.42	-5.33	4.48		0.00	>1000
Poor[e]	-0.94	1.15		0.04	3.75	-3.37	1.27		0.00	2.14
Home Value[f]	-0.01	0.05		0.91	1.09	0.00	0.07		0.89	1.11
Public Asst[g]	-2.25	3.35		0.00	74.37	-6.70	2.59		0.00	118.87
Midwest[2]	0.16	1.28		0.09	14.48	-14.88	0.84		0.00	>1000
Northeast[2]	1.28	1.35		0.25	50.96	-2.26	1.12		0.00	10.53
West[2]	0.83	1.31		0.17	29.99	1.57	1.52		0.07	316.17
Airport Hub	-0.10	0.97		0.14	6.04	1.18	0.86		0.11	97.74
International	-0.47	1.10		0.07	5.40	-0.79	0.59		0.02	11.84
Constant	18.21	11.15				-5.28	8.34			

Note. [1]Group 5 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 6

Multinomial Logistic Regression with Group 6 as Reference (N = 132)

	GROUP 1[1]					GROUP 2[1]					GROUP 3[1]				
	b	se	*p*		OR	b	se	*p*		OR	b	se	*p*		OR
Population[a]	-1.81	0.52	***	0.06	0.45	-1.40	0.54	***	0.08	0.71	-0.38	0.31		0.37	1.26
White[b]	-0.64	0.68		0.14	1.99	-0.02	0.69		0.25	3.80	-0.59	0.68		0.15	2.09
Kids[c]	1.93	2.83		0.03	>1000	5.42	3.05	+	0.58	>1000	2.97	2.75		0.09	>1000
Household[d]	2.17	7.06		0.00	>1000	-3.33	7.42		0.00	>1000	-4.02	7.17		0.00	>1000
Poor[e]	1.64	2.43		0.04	605.50	4.11	2.50		0.46	>1000	2.46	2.33		0.12	>1000
Home Value[f]	-0.03	0.08		0.83	1.13	0.00	0.07		0.86	1.15	0.03	0.06		0.91	1.16
Public Asst[g]	10.08	6.43		0.08	>1000	7.60	6.41		0.01	>1000	-1.61	7.25		0.00	>1000
Midwest[2]	14.07	914.06		0.00	>1000	13.35	914.06		0.00	>1000	14.70	914.06		0.00	>1000
Northeast[2]	0.23	2.51		0.01	172.81	0.36	2.55		0.01	211.49	1.28	2.56		0.02	545.68
West[2]	-5.78	2.53	*	0.00	0.44	-3.85	2.30	+	0.00	1.92	-1.63	2.36		0.00	20.02
Airport Hub	-3.83	1.83	*	0.00	0.78	-2.98	1.85		0.00	1.90	13.39	>1000		0.00	>1000
International	-0.39	1.72		0.02	19.42	-0.58	1.71		0.02	16.03	0.74	1.89		0.05	85.14
Constant	-2.7	18.00				-7.98	18.22				-11.28	1065.65			

Note. [1]Group 6 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group

$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R^2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

Table D 6 continued

	GROUP 4[1]					GROUP 5[1]				
	b	*se*	*p*	*OR*		*b*	*se*	*p*	*OR*	
Population[a]	-0.83	0.34	*	0.22	0.84	-0.82	0.33		0.23	0.85
White[b]	-0.73	0.61		0.15	1.59	-0.06	0.58	+	0.30	2.95
Kids[c]	0.09	2.70		0.01	215.58	0.45	2.57		0.01	241.38
Household[d]	0.70	6.71		0.00	>1000	5.33	6.41		0.00	>1000
Poor[e]	2.44	2.15		0.17	778.90	3.37	2.11	+	0.47	>1000
Home Value[f]	0.00	0.06		0.89	1.12	0.00	0.06		0.90	1.12
Public Asst[g]	4.45	6.17		0.00	>1000	6.70	5.85		0.01	>1000
Midwest[2]	15.04	914.06		0.00	>1000	14.88	914.06		0.00	>1000
Northeast[2]	3.54	2.41		0.30	>1000	2.26	2.36		0.09	971.24
West[2]	-0.75	2.20		0.01	35.38	-1.57	2.13		0.00	13.58
Airport Hub	-1.28	1.82		0.01	9.87	-1.18	1.73		0.01	9.18
International	0.31	1.73		0.05	40.29	0.79	1.66		0.08	56.93
Constant	0.66	17.14				-17.56	16.22			

Note. [1]Group 6 is the reference group. LR Chi^2 (60) = 162.02. [2]South region is the reference group
$^{+}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Pseudo R2 = .37

Log Likelihood = -140.66

[a]Population per square mile (1 unit = 1000 people). [b]Percent population that is white (one unit = 10%). [c]Percent of households that have kids less than 18 years old (one unit = 10%). [d]Average household size. [e]Percent population that reported an income on the 2010 U.S. Census that classifies as poor (one unit = 10%). [f]Median home value (1 unit = $10,000). [g]Percent population that receives financial public assistance (one unit = 10%).

VITA

VITA

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University of South Carolina, August 2005- May 2009
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B.A. Music

Funded Research

Reason: Graduate Research Assistantship, Fall 2015-Spring 2016
(Dr. Karen Marais, PI)

Faculty Supervisor: Dr. Mary E. Johnson (Co-PI)

Sponsor: Federal Aviation Administration for PEGASAS (Partnership to Enhance General Aviation Safety, Accessibility and Sustainability)

Description: Development of General Aviation flight data recorder safety tool for smartphone or tablet and enhance flight data monitoring for the GA community

Publications

Spence, T.B., Vath, B., Kwak, Y.Y., & Johnson, M.E. *Evaluating a Fine Based Approach to Noise Sustainability for an Airport Community*. Manuscript submitted for publication in the *International Journal of Sustainable Transportation*.

Spence, T.B., Fanjoy, R.O, Lu, C-t., & Schreckengast, S.W. (2015). International Standardization Compliance in Aviation. *Journal of Air Transport Management*, *49*, 1-8. doi: 10.1016/j.jairtraman.2015.06.015

Spence, T.B. M.S., Purdue University, May 2013. International Standardization Compliance in Aviation. Major Professor: Richard O. Fanjoy

Current Manuscripts and Research Projects

Leib, S., Lu, C-t., Sun, R-s., & Spence, T. *Evaluation of safety programs at aviation organizations in Tianjin, China, with ICAO SMS standards*. Manuscript in preparation.

Spence, T.B., Winter. S.R., & Fanjoy, R.O. *Longitudinal analysis of the media response in the wake of a major aviation accident*. Manuscript in preparation.

Spence, T.B. & Mott, J.H. *Solutions to noise mitigation at the largest United States Airports*. Manuscript in preparation.

Spence, T. B., & Keller, J. *GA safety and accident prevention on approach to landing*. Manuscript in preparation.

Conference Proceedings

Walala, M. & Spence, T.B. (2015, January). *Assessing the commercial aviation impact of the year 2000 open skies agreements between the United States and African countries with longstanding flights*. Paper presented at the annual meeting of the A3IR Conference, Phoenix, AZ.

Rudari, L. Spence, T.B., Sperlak, L.A., Geske, R., Walala, M., Morris, C., …, & Thanos, M. (2014, October). *CRM-based training and its effect on aviation accident rates in the U.S. from 1960 to 2013*. Paper presented at the 67th Annual International Air Safety Summit, Abu Dhabi, UAE.

Winter, S.R., Leib, S. M., Geske, R. C., Spence, T. B., Sperlak, L. A., Rudari, L., & Cestari, C. D. (2013, October). *An examination of factors leading to runway excursions*. Paper presented at the 66th Annual International Air Safety Summit, Washington, D.C.

Conference/Symposium Presentations and Attendance

Presented

A3iR Conference, Phoenix, AZ (2015, January): *Assessing the commercial aviation impact of the year 2000 open skies agreements between the United States and African countries with longstanding flights*.

Purdue Aviation Graduate Research Symposium (2012, April): *Evaluation of safety programs at aviation organization in Tianjin, China, with ICAO SMS standards*,

University Aviation Association Student Seminar, Washington, D.C. (2012, January): *International Civil Aviation Organization Policy Standards and Recommended Procedures*,

Attended

Flight Safety Foundation, Miami, FL. 68th International Air Safety Summit, November 2015.

International Civil Aviation Organization, Montreal, CA. Sixth Worldwide Air Transport Conference: Sustainability of Air Transport, March, 2013.

Purdue Aviation Graduate Research Symposium, Purdue University, April 2012

International Safety Management Systems Workshop, Tianjin, China, March 2012.

University Aviation Association Student Seminar, Washington, D.C., January 2012.

Dissertation

Title: An Evaluation of Noise Reduction Strategies at Large U.S. Commercial Airports: A Policy Analysis and Framework Classification

Committee Chair: Dr. Richard O. Fanjoy

Committee Members: Dr. Thomas Q. Carney, Dr. Sarah M. Hubbard, Dr. Patricia A. Boling

Completion: May, 2016

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AT 145, Private Pilot Flight Course

AT 243, Commercial Pilot I Flight Course

AT 248, Commercial Pilot II Flight Course

AT 253, Instrument Pilot and Commercial Pilot Completion Flight Course

AT 210, Instrument Pilot Simulator I Course

AT 211, Instrument Pilot Simulator II Course

Scholarships and Awards:

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Award: $16,065/year

Graduate Teaching Assistantship at Purdue University
Fall 2011-Spring 2013

Nominated for and CCC&TI winner of NCCCS Academic Excellence Award, 2011

Nominated as a Presidential Member for the National Society of Leadership and Success, 2010

President's Honor Role at CCC&TI

President’s Honor Role at the University of South Carolina

Dean’s Honor Roll for College of Liberal Arts and Sciences

School of Music Scholarship for clarinet studies

Shirley McCue Knox Bicen Music Award

Member, National Society of Collegiate Scholars

Member, Kappa Psi, National Honorary Fraternity for College Band Members

Member, Gamma Beta Phi, National Honorary Service Organization

Research Interests

International Aviation, ICAO Standardization, Aviation Policy, Safety Management, Human Error, Human Factors

Software Experience

Microsoft Office: Extensive use of Word, Excel, and PowerPoint

Statistical packages: SAS 9.4, SPSS 23, STATA 14, R, Mplus 7.4

Other: NVivo 10, Qualtrics Survey Software

Leadership Experience and Service

Flight Safety Foundation, Treasurer, Fall 2014-2015

Internship at the United States Department of State: Office of Aviation Negotiations and Office of Transportation Policy, Summer 2014

Flight Safety Foundation, Vice President of Research, Fall 2013-2014

Flight Safety Foundation (first student chapter) Treasurer, 2012-2013

Purdue Aviation Research Symposium, Lead Chair, 2012-2013

Hangar 6 Group Tours of Purdue aviation facilities and simulator lessons, Including aviation camps, JROTC, Cub Scouts, and Nanshan Group Corporation

Co-planner for the International Safety Management Systems Workshop in Tianjin, China, Spring 2012

Member, Purdue Aviation Graduate Council, Fall 2011 to present

Hosted National Intercollegiate Flying Association SAFECON at CCC&TI, 2010

Blue Ridge Flying Eagle, CCC&TI, Secretary, 2010-2011

Hosted Southeast District Convention, Kappa Psi, 2009

Kappa Psi, Secretary, 2008-2009

Public Relations Committee Chair, Kappa Psi, 2008-2009

Clarinet Association at the University of South Carolina, co-founder and treasurer, 2006-2009

Other Achievements:

Purdue University Homeland Security Institute Courses Completed:
- CNIT 511: Foundations in Homeland Security
- CNIT 512: Managing Resources and Applications for Homeland Security

Certified Flight Instructor, 2010
- Advanced Ground Instructor Rating in 2010
- Single Engine/Multi-Engine Instrument and Commercial Ratings, 2010

University Concert Ensembles, 2006-2009

University of South Carolina Marching Band 2005-2009