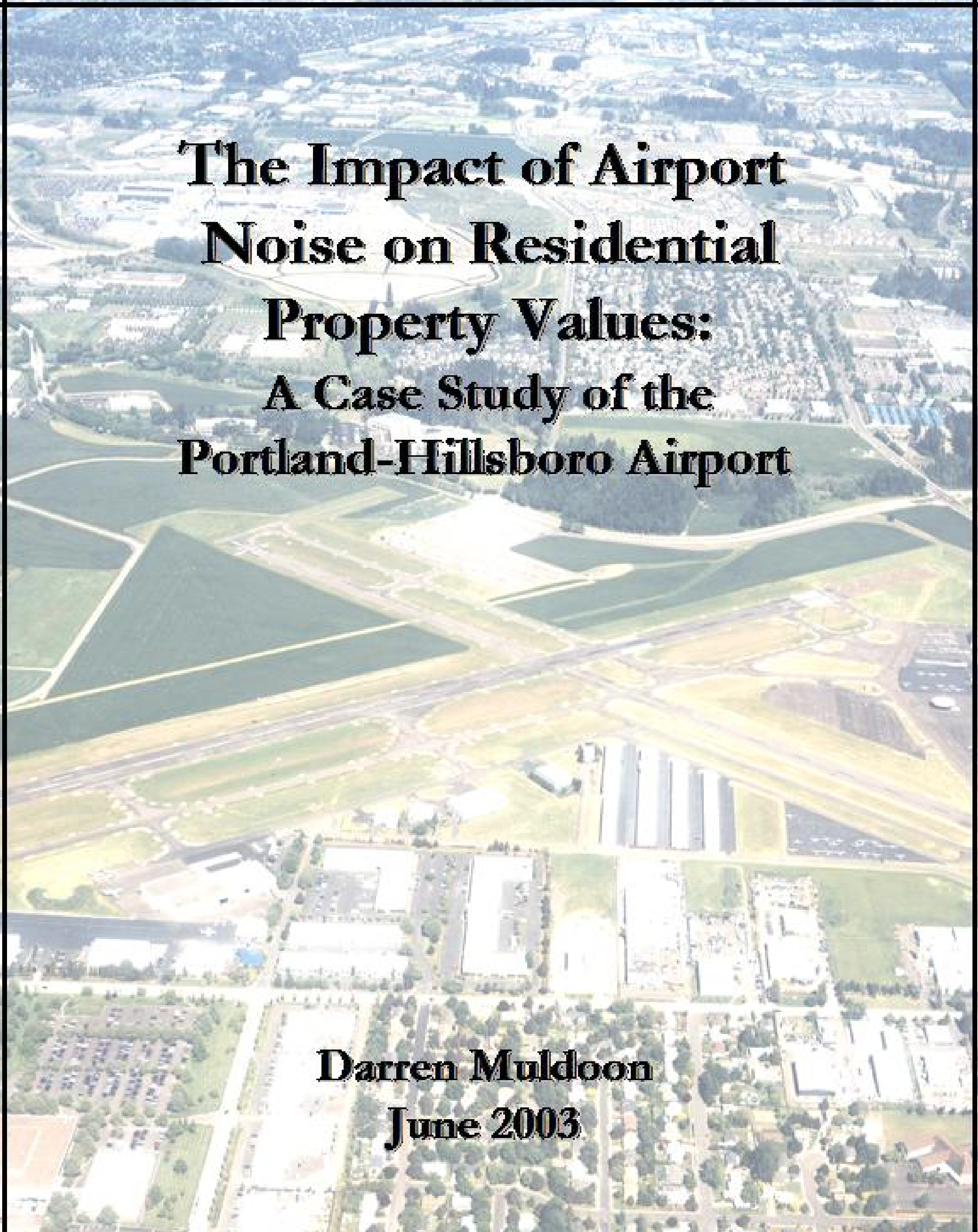

The Impact of Airport Noise on Residential Property Values:

A Case Study of the Portland-Hillsboro Airport

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June 2003

FIELD AREA PAPER

This Field Area Paper was completed in June of 2003. Dr. Jennifer Dill served as the primary reader. Dr. Jim Strathman served as the second reader.

This paper was completed to fulfill a curriculum requirement for the Master of Urban and Regional Planning degree at Portland State University.

NOTE:

- This report is based on noise contour data provided by the Port of Portland for educational purposes only, and is not a formal finding by the Port of Portland. With new aircraft technology, flight track changes, weather patterns, and other factors, noise contours are constantly changing. Due to errors in measurement, data collection, transferring of data from one form to another, methodologies, and the age of the noise contours (1995) used in this report, the Port of Portland does not accept the results or conclusions in this report. This report was completed for educational purposes only.

A SPECIAL THANKS TO:

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ABSTRACT

This work builds on previous studies researching airport noise and residential property values. The hedonic price method is used to explore the relationship between residential property values and airport noise in the vicinity of the Portland-Hillsboro Airport, a general aviation airport in Hillsboro, Oregon. Controlling for the year the property sold, empirical results suggest that there is no statistically significant negative relationship between airport noise and residential property values.

INTRODUCTION

A number of studies have examined the relationship between airport noise and residential property values. Several studies provide data on an estimated percentage loss in residential real estate values due to airport noise of varying intensity. Most studies have concluded that aircraft noise decreases the value of residential property sale prices located near airports. While previous studies analyzed large commercial airports, little research has been completed for smaller general aviation airports. This study uses the hedonic pricing technique to determine the impact of both airport noise and the proximity to the airport on residential property values in the vicinity of the Portland-Hillsboro Airport in Hillsboro, Oregon.

There are hundreds of detrimental conditions (DCs) that may impact property market values. Airport noise is an externality that is imposed onto property owners and generally on a permanent basis (Bell 2001). For most people, noise is a significant issue and there is a segment of the population that will not live under a flight path. At the other extreme, there is a certain segment of the population that will purchase a property close to an airport if enticed by a reduced property price. In the middle of the spectrum are the people that own or purchase property in the vicinity of an airport that is impacted by airport noise. Since this study focuses on property sale values near an airport, the results may indicate the willingness to pay of people in the middle of the spectrum for residential property near an airport.

Relative to many other detrimental conditions such as environmental contamination and geotechnical issues, airport noise is more straightforward to study and assess (Bell, 1997). The most fundamental aspect of real estate valuation studies is that conclusions must be based upon market data. In very few cases will the market value be significantly less than the assessed value since the property owner has the right to appeal any such determination. Real estate law in most states requires sellers to reveal noise and other nuisance factors, including airports, so prospective buyers are warned. Realtors have reported cases where offers were withdrawn or lowered in the vicinity of airports as a result of airport activity (Kranser, 1997). Actual market value is the statistic that is most impacted by airport noise.

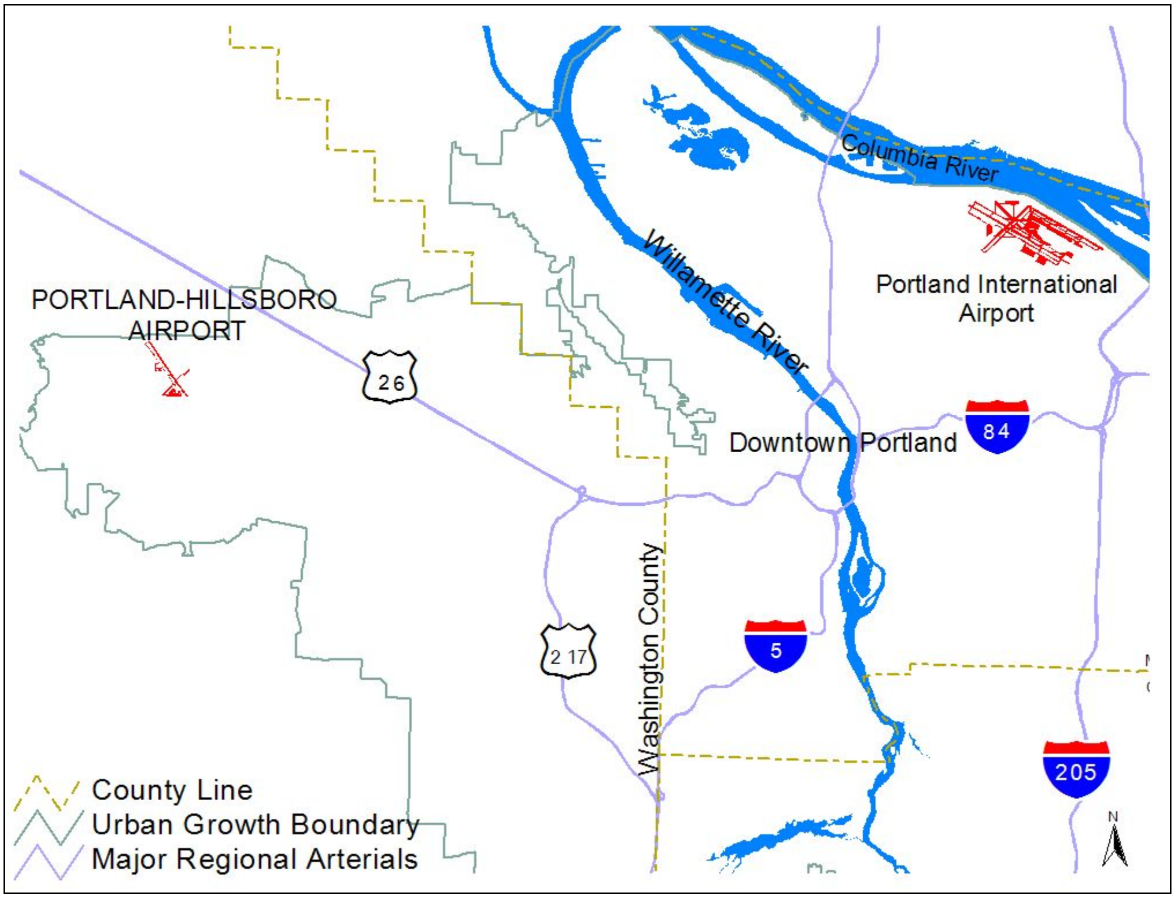
If an airport were nonpolluting, land rentals would be expected to decline with increased distance from the airport, and proximity to an airport may have certain positive effects on residential property values. These effects may include transportation network improvements, accessibility to jobs, and reduction in travel costs. Because of the positive and negative effects, the larger the airport, the more affect these effects will have on surrounding properties. Therefore, the larger the airport, the net effect on housing may not be negative because of the accessibility to jobs and other factors (Crowley, 1973). Employment opportunities exist at airport sites as well as commercial and industrial facilities that develop in the vicinity of an airport. For individuals that might work at or near an airport, or use the airport for travel, the benefits of proximity can be reflected in property values. Therefore, the net effect of property values can be positive or negative. Failure to account for accessibility to an airport could lead to bias in the hedonic estimated price for airport noise. Most people do not use general aviation airports travel, so accessibility is not a positive factor for general aviations.

Since an airport produces transport services as well as air and noise pollution, it is reasonable to expect external economies for industrial/commercial use and external diseconomies for residential use. Another factor in studying the impact of airports is the question of whether property values are significantly less for non-residential purposes; however, it is difficult to obtain data on commercial/industrial sales on the same basis as on residential because of difficulties in determining precisely what was sold and obtaining data on non-residential properties (Crowley, 1973). For residential uses, if a diminution in value is concluded, and if the home could be physically transported to an identical location on an identical lot in another part of the area, its value would increase, and the amount of its increase is the depression in value caused by proximity to the airport (Lane, 1994).

The Portland-Hillsboro Airport is a general aviation airport located in Hillsboro, Oregon a suburb to the west of Portland (Figure 1). Hillsboro and surrounding areas experienced double-digit population growth in the 1990's. Before thia large population growth, Hillsboro-Portland Airport was largely surrounded by open farmland, especially underneath the flight paths for both airport runways. However, as the area increased in population, open land near the airport developed with mostly single-family residential. Additionally, the airport experienced an increase in the number of operations at the airport. In terms of the number of airplane operations in Oregon, the Portland-Hillsboro Airport ranks second to Portland International Airport. With increased operations and new development around the airport, Hillsboro citizens have recently expressed their concerns of airport noise on the livability of the area on their property values.

This report analyzes home sales in an area near the airport, an approximate half-mile buffer of the airport's noise contours, an area underneath the airport flight paths with higher noise level than areas not near the airport. Although noise is probably the most important single impact that results from living under and airport's approach/departure flight tracks, the analysis of this paper does not fully confirm causality between noise effects and reduced property values. It is important to remember that the following analysis addresses the issue of depressed but not declining land values. Depressed land values means the value of the land is increasing, but the rate is less compared to land values not impacted by airport activity.

Figure 1: Location of the Portland-Hillsboro Airport



Data Source: Metro RLIS (May, 2003 update)

This report is divided into nine main sections: (1) Airport Noise Background; (2) Airport Land Use Planning; (3) Aviation and Airport Background; (4) Literature Review; (5) Explanation of the Hedonic Theory; (6) Methodology; (7) Models and Empirical Results; (8) Discussion of Results; and (9) Conclusion.

AIRPORT NOISE BACKGROUND

Because of its routine and everyday occurrence, noise is usually perceived as the most significant adverse impact of airport activity. The Federal Aviation Administration (FAA) develops noise exposure maps by using a computer model called the Integrated Noise Model (INM). The INM depicts the airport's noise environment by integrating the aircraft flight tracks, the number of annual operations, the type and mix of airplanes serving the airport, and the time of day the aircraft are flown (Booz-Allen & Hamiliton, 1994).

One way to describe the sound environment is to measure the maximum sound level, such as a passing automobile or bus, in decibels (dB). Because the ear's pattern of response is more logarithmic in nature, decibels are measured on the log scale. The perception of noise doubles in loudness for every 10 dB increase in sound level. Therefore, an 80 dB is perceived to be four times louder than a 60 dB sound. Table 1 illustrates common sounds and their noise levels in dB (FAA Office of Environment and Energy, 1999).

Table 1: Common Sounds and Their Noise Levels

dB	Sound
110	Rock Band
100	Gas Lawn Mower at 3 ft.
90	Food Blender at 3 ft.
80	Garbage Disposal at 3 ft.
70	Vacuum Cleaner at 10 ft.
60	Ordinary Conversation
50	Dishwasher in Next Room
40	Small Theater
30	Watch Ticking
20	Quiet Rural Nighttime
10	Rustling Leaves

Source: Oregon Department of Aviation, Airport Land Use Compatibility Guidebook, 2003

A typical background noise level in urban areas is about 55 dB during daytime hours and 40 dB during nighttime hours. Because the noise level in urban areas is 55 dB, the noise impact threshold for study ought to be greater than or equal to 55 dB. At noise levels above 75 dB, the Environmental Protection Agency (EPA) cautions that more severe health effects may occur for some portion of the population, including temporary hearing loss. Aircraft noise is continuous, meaning the maximum sound level is not at one point, but instead over duration of time. Studies have shown that human response to noise involves both the maximum level and its duration, so the maximum sound level in decibels alone is not sufficient to evaluate the effect of aircraft noise on people (FAA Office of Environment and Energy, 1999).

A second way to describe sound environment other than in decibels is to measure the Sound Exposure Level (SEL). The SEL is the total sound energy of a single sound event and takes into account both its intensity and duration. SEL is the sound level experienced if all sound energy of a sound event occurred in one second. Normalizing to a duration of one second allows the direct comparison of sounds of different durations. A more effective way to describe both the number of events and the sound exposure level of each event is the time-average of the total sound energy specified over a period, referred to as the equivalent sound level (Leq) (FAA Office of Environment and Energy, 1999).

An additional factor important in measuring the sound environment is the occurrence of sound events during the nighttime. Studies have concluded most people are more sensitive to sound events at night because the background sound levels are normally lower at night because of decreased human activity. Therefore, a "penalty" may be added to sound levels that occur during night hours. A 10 dB penalty is added to sound levels occurring between 10:00 PM and 7:00 AM. The 24-hour average sound level, including the 10-dB penalty is known as the day-night average sound level (DNL). The 10-dB penalty means that one nighttime sound event is equivalent to 10 daytime events at the same sound level (FAA Office of Environment and Energy, 1999).

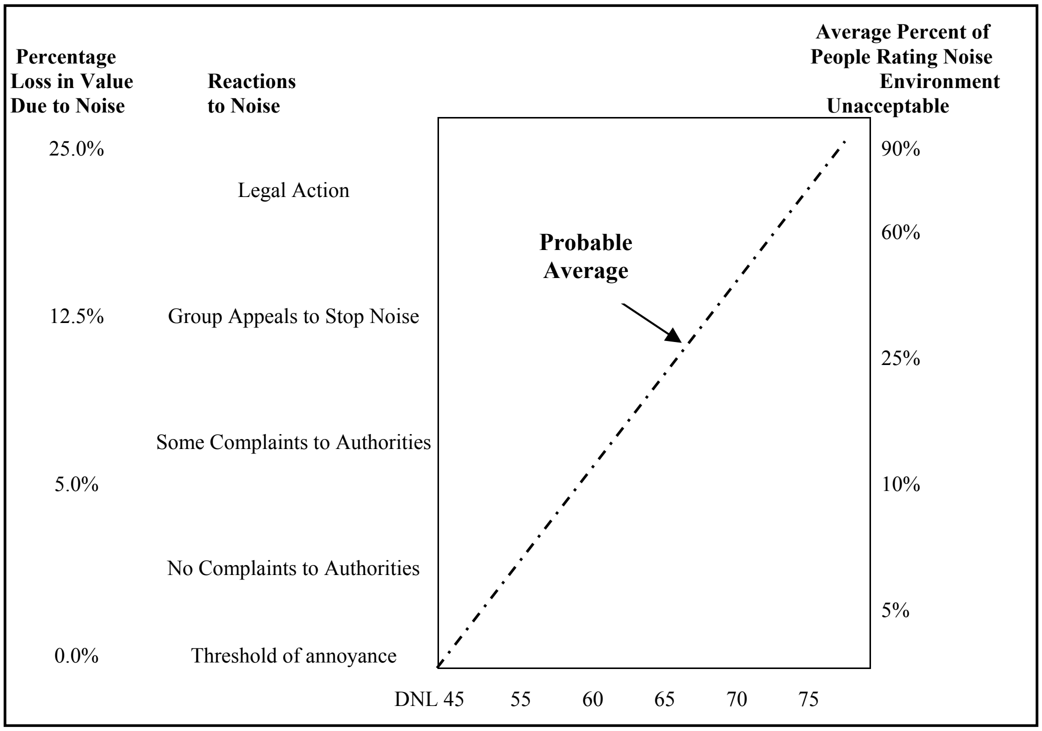
Noise impact areas for an airport are identified by noise contours. The methodology to define aircraft noise levels involves the use of the FAA's Integrated Noise Model. The model computes the associated noise exposure level for the specific aircraft and engine thrust at that point along the route of the flight. Noise exposures are summed for each grid located and indicated by a series of contour lines on a map of the airport and its environs. Although lines on the map tend to be viewed as definitive, the contour lines are only a planning tool. Noise contours for an airport allow a planner to identify areas that are likely to be impacted by aircraft noise, to estimate the amount of noise, and plan accordingly (Oregon Department of Aviation, 2003).

Noise contours expressed in DNL is the preferred manner to measure noise by the FAA. The higher the DNL level the greater the average noise exposure. DNL contours are used to provide guidance in the development of land use controls, such as zoning and building codes (Hillsboro Airport Master Plan, 1996). Aircraft noise contours for the Portland-Hillsboro Airport in this report are from 1996 Hillsboro Airport Master Plan, and the noise contours are 1995 noise conditions using the DNL descriptor.

AIRPORT LAND USE PLANNING

The development of land uses that are not compatible with airports and aircraft noise is a growing concern across the United States. In addition to aircraft noise, there are other issues, such as safety and environmental impacts around airports that need to be considered when addressing the overall issue of land use compatibility (FAA, Land Use Compatibility and Airports, 1998). The objectives of compatible land use planning are to encourage land uses that are generally considered to be incompatible with airports to locate away from airports, and to encourage land uses that are more compatible to locate around airports. Aircraft noise continues to be an issue at many airports, especially where airport capacity and aircraft operations are increasing. The problem of aircraft noise has been dealt with through operating requirements and quieter aircraft and also by soundproofing structures. As a result, the number of people exposed to noise levels of 65 dB or more has dramatically declined in the last twenty-five years (FAA Office of Environment and Energy, 1994). Because airport noise is the number one environmental concern at major airports, capacity and operation expansion is often slowed by public concern with noise exposure. Figure 2 illustrates people's response to aircraft noise and the estimated percentage loss in value due to noise. The line on the graph is the probable percent average of people rating the noise environment unacceptable and probable average percentage loss in value to due to noise. For example, at a DNL of 55, the percentage loss in value due to noise is about 2 percent, the average percent of people rating noise environmental unacceptable is about 7 percent, but there are no complaints to authorities.

Figure 2: Response to Noise and Impact on Property Values



Source: Booz-Allen & Hamilton, Inc., "The Effect of Airport Noise on Housing Values: A Summary Report," Office of Environmental and Energy, Federal Aviation Administration (September, 1994).

Figure 2 highlights the importance of the economic valuation of noise. Although the federal government cannot dictate local land use policies, it can play a role in facilitating the coordination between airports, local, county, and regional planning agencies to ensure that compatible land use planning occurs around airports (Oregon Department of Aviation, 2003). The benefits of noise monitoring include the following:

- Build a noise level database that can be used to evaluate noise over time
- Spot trends in aircraft procedures that may impact the local community
- Measure impact of proposed operational changes
- Assist with complaint research
- Assist with airport planning

There are many entities involved in implementing programs related to land use compatibility around airports. At the federal level, the primary agency responsible for aviation related land use compatibility is the FAA. The FAA is responsible for federal laws and regulations affecting the aviation industry. The FAA has been actively supporting programs to minimize noise impacts. These include phase out of noisier older aircraft, supporting airport noise compatibility programs, and funding of mitigation measures. The FAA is the primary funding source for land acquisition to provide open space around airports and noise related mitigation measures (Oregon Department of Aviation, 2003). Other entities include state government, local government, or the owner and operator of the airport.

FEDERAL LEGISLATION

The Aviation Safety and Noise Abatement Act of 1979 (ASN) required that a single system be developed for measuring noise and determining noise exposure caused by airport operations and required identification of land uses normally compatible with exposure to noise. The FAA issued noise guidelines to land use planning near airports as part of its Airport Compatibility Program found in Part 150 of the *Federal Aviation Regulations*. Under FAR Part 150, local jurisdictions can prepare and submit to the FAA a noise exposure map for the airport environs and a noise compatibility plan. This voluntary program applies to all publicly owned, public use airports that are included in the National Plan of Integrated Airport Systems (NPIAS). The NPIAS identifies the type and estimated costs of airport development eligible for FAA Airport Improvement Program (AIP) funds (Oregon Department of Aviation, 2003). Other provisions established by FAR Part 150 include:

- Making the decibel the universal noise measurement tool
- Making the DNL the universal noise contour measure
- Defining land uses that are acceptable for areas within each DNL noise contour.

After DNL noise contours are developed for an airport, three basic noise impact areas can be identified. The severe noise impact areas include those areas contained within the 70 DNL noise contour and above. The substantial noise impact categories are areas impacted by the 65 DNL to the 70 DNL contour. Areas impacted by the 55 DNL up to the 65 DNL contour are within the moderate noise impact category. Areas exposed to 55 DNL or less are not considered seriously impacted by noise. FAR Part 150 describes acceptable types of land uses for each DNL sound level. Land uses that should not be located within areas exposed to 65 DNL and above include all residential development. When public institutions such as schools, hospitals, and churches are constructed within noise contours of 65 DNL or higher, measures should be taken to achieve reduced noise levels (Oregon Department of Aviation, 2003). Additional FARs that impact airport land use compatibility includes:

- *FAR Part 36*: Categorizes aircraft by level of noise the aircraft generates (Stage 1, Stage 2, Stage 3), and outlines a timeline of when louder aircraft (Stage 1) need to be retired.
- *FAR Part 91*: Mandated a deadline of December 31, 1999 for the retirement of all Stage 2 aircraft. Waivers authorizing extensions may be granted, but Stage 2 aircraft will no longer be permitted to operate after December 31, 2003. This transition to a quieter fleet mix will result in smaller noise contours, reducing the noise impacts in areas surrounding airports.
- *FAR Part 161*: Defines requirements and procedures for airports to follow when implementing Stage 3 aircraft noise and access restrictions (Oregon Department of Aviation, 2003).

These FARs have less impact on general aviation airports, especially general aviation airports without jet service. The Portland-Hillsboro airport has some private jets.

Since 1979, with the Part 150 study, federal agencies have considered the DNL sound level of 75 dB or greater as incompatible with all residential land uses. Lands exposed to DNL 64-75 dB are regarded as “normally” incompatible with residential use, while lands exposed to a DNL of less than 65 dB are regarded as “normally” compatible with residential use, based on the Safety and Noise Abatement Act of 1979, the FAA adopted noise compatibility standard. Furthermore, the FAA considers 1.5 dB or more above 65 dB as a significant addition of noise. A federal action resulting in such a noise increase requires an environmental impact statement. Commercial and industrial zoned land uses are compatible but should require additional insulation to structures to reduce noise levels. The DNL measure was used in the Part 150 study because it correlates with degree of human response such as annoyance, communication interference, and hearing loss (FAA Office of Environment and Energy, 1994).

OREGON LAND USE AND AIRPORT PLANNING

Since 1974, Oregon's Land Use Planning Act has required all cities and counties to develop and adopt comprehensive plans. These plans must be updated through periodic review to ensure that the plan continues to meet the policies of the state of Oregon. Statewide Planning Goal 12 is the goal directly applicable to airport planning in the context of periodic review. Goal 12 promotes safe, convenient, and economic statewide transportation networks, including passenger and air freight transportation. In order to comply with Goal 12, city and county comprehensive plans must include a transportation element that addresses state requirements for airport planning and compatibility with surrounding land uses. To aid in implementing Goal 12, the Oregon Department of Land Conversation and Development (DLCD) adopted the Airport Planning Rule (APR). The APR establishes a series of local government requirements pertaining to aviation facility planning (Oregon Department of Aviation, 2003).

The Statewide Transportation Planning Rule (TPR) also contains language that is applicable to airport planning. Transportation System Plans (TSPs) are required to contain elements intended to preserve local components of the state's public use aviation system. The TPR requires local jurisdictions to adopt land use regulations for land uses within airport noise corridors. The Oregon Department of Transportation (ODOT) prepared and adopted the 2000 *Oregon Aviation Plan* (OAP) as part of the *State Transportation System Plan*. The purpose of the OAP is to provide state policy guidance and a framework for planning and operation of public use airports (Oregon Department of Aviation, 2003).

Cities and counties are responsible for ensuring compatibility of land uses and establishing appropriate zoning requirements around airports. The impact of land use decisions that result in incompatible land uses by allowing residential development to occupy noise impact areas can limit an airport's ability to expand facilities or expand operations. Oregon's Transportation Planning Rule contains strong language requiring local jurisdictions to develop land use regulations and adopt measures to protect public use airports by controlling land uses within airport noise corridors (Oregon Department of Aviation, 2003).

State Department of Environmental Quality (DEQ) standards for noise abatement, control, and mitigation are outlined in the Oregon Aviation Rules (OAR). These rules define and establish parameters for the Airport Noise Abatement Program, airport noise standards, and airport noise impact boundaries. The State of Oregon accepts the DNL noise contour method as the primary method for measuring noise around an airport. Since the 55 DNL noise contour can extend well beyond airport boundaries, the OAR also identifies noise abatement methods, such as soundproofing and land acquisitions (Oregon Department of Aviation, 2003).

The State of Oregon regards the 60 DNL and 55 DNL contours as significant noise levels, different from the FAA's standards. Therefore, the State recognizes that in some instances, land use controls and restrictions that apply to the 65 DNL may be appropriate for applications to areas impacted by the 55 DNL contour or greater. The Oregon Department of Environmental Quality (DEQ) finds that noise pollution associated with Oregon airports threatens the public health and welfare of residents living near airports. DEQ has adopted Oregon Administrative Rule Chapter 340, Division 35: "Noise Control Regulations" and an "Airport Noise Control Procedure Manual." This rule establishes procedures for an airport sponsor to use when a noise contour map or airport land use plan is needed, and also establishes the 55 DNL as a study boundary for planning and zoning measures (Oregon Department of Aviation, 2003). Therefore, this study examines home sales affected by airport noise by using the 55 DNL contour as the noise threshold for nuisance.

The purpose of noise compatibility planning is to minimize the extent to which noise impacts create an annoyance. The best approach is to allow as few people as possible to occupy highly noise-impacted areas as possible. Alternatives include shielding people from noise, educating people of noise issues, and allowing land uses that are not particularly noise sensitive.

AVIATION AND AIRPORT BACKGROUND

GENERAL AVIATION

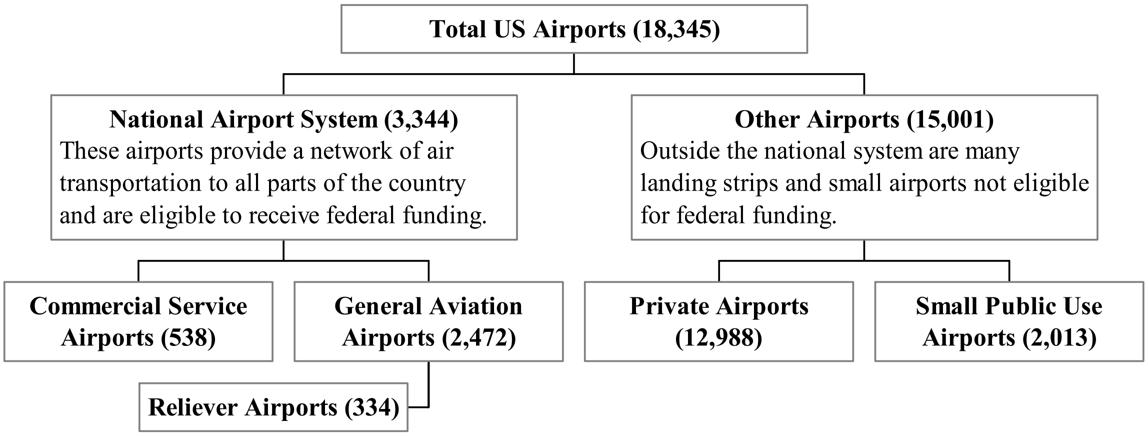
The FAA classifies the Portland-Hillsboro Airport as a General Aviation Airport, and more specifically, a Reliever Airport. General aviation is defined as all aviation other than commercial airlines and military aviation. General aviation carries 166 million passengers annually on general aviation aircraft ranging from two-seat training aircraft to intercontinental business jets. Facts about general aviation include:

- 75 percent of all US flights are made on general aviation aircraft
- Of the entire US civilian aircraft fleet, 96 percent are general aviation aircraft
- There are 25.4 million flight hours annually and 35.8 million takeoffs and landings.
- There are 18,200 US landing facilities, including 13,175 airports
- More than 5,400 communities rely on general aviation for their air transportation needs, compared to 600 communities served by scheduled service (Aircraft Owners and Pilots Association, 2002).

Airports in the United States are divided into two groups: those airports that are part of the National Airport System, and Other Airports. National Airport System airports provide a network of air transportation to all parts of the country and are eligible to receive federal funding. Other airports are smaller airports, private or public, that are not eligible for federal funding. A *Commercial Service Airport* boards at least 2,500 passengers a year in scheduled passenger airline service. These airports are labeled primary if they have more than 10,000 passengers a year and non-primary if they have fewer. Some Commercial Service Airports are further defined as *Hub Airports* based on what percentage of all passengers flying in the current year use them. Hub airports are then classified as Small, Medium, or Large Hub Airports.

A Large Hub Airport handles more than 1 percent of all passengers flying during a given year (Aircraft Owners and Pilots Association, 2002). The figure below illustrates the categories of airports as defined by the FAA.

Categories of Airports in the United States



Total US Airports (18,345)

National Airport System (3,344)
These airports provide a network of air transportation to all parts of the country and are eligible to receive federal funding.

Other Airports (15,001)
Outside the national system are many landing strips and small airports not eligible for federal funding.

Source: Federal Aviation Administration, 2002

General Aviation Airports comprise the largest single group of airports. There are 2,806 General Aviation airports in the United States. These airports are eligible for public funding depending on its size. A subcategory of General Aviation Airports are *Reliever Airports* that are designated by the FAA to relieve congestion at Commercial Service Airports, usually in a major urban area, to provide more General Aviation access to the local community (Aircraft Owners and Pilots Association, 2002). The FAA officially classifies the Portland-Hillsboro Airport as a reliever airport of PDX.

PORTLAND-HILLSBORO AIRPORT BACKGROUND AND HISTORY

The Portland-Hillsboro Airport is located in the northeastern corner of the City of Hillsboro on the west side of the Portland-Metropolitan region in area known as the Sunset Corridor. The airport was first built as a private facility in 1928. The City of Hillsboro purchased the airport in 1935 and built two paved 4,000-foot runways during World War II. Through land acquisition, the property grew from 280 acres to 424 acres by 1965 when the airport was transferred to the Port of Portland. The Port of Portland added parallel taxiways in the 1960's, and a major property expansion, the extension of the primary runway, a terminal building, and an air traffic control tower in the 1970's (Hillsboro Master Plan, 1996).

The airport plays an integral role as a general aviation reliever airport of Portland International Airport (PDX). The airport currently encompasses 877 acres, and is by far the busiest general aviation airport in Oregon and the second busiest to PDX in annual operations (Hillsboro Airport Master Plan, 1996). Table 2 illustrates the top ten airports in terms of number of operations in Oregon. An operation is defined as a takeoff or a landing.

Table 2: Annual Operations of Oregon Airports (2001)

City	Airport Name	Operations
Portland	Portland International	277,082
Hillsboro	**Portland-Hillsboro**	**222,300**
Troutdale	Portland-Troutdale	107,460
Eugene	Mahlon Sweet Field	95,902
Aurora	Aurora State	73,895
Klamath Falls	Klamath Falls Regional	68,087
Medford	Rogue Valley Intl	67,258
McMinnville	McMinnville State	63,500
Scappoose	Scappoose Industrial	60,155
Redmond	Roberts Field	57,214

Source: State of Oregon Department of Aviation Land Use Compatibility Guidebook, 2002

The number of annual operations is typically used in the aviation industry to classify an airport's size. An alternate and less common measure is the number of based aircraft at the airport. This measure is more common for general aviation airports like Hillsboro, and not common for commercial airports such as PDX. Table 3 below illustrates the top ten airports in Oregon in terms of the number of based aircraft. As of 2000, there were over 350 aircraft based at the Portland-Hillsboro Airport (Oregon Department of Aviation, 2003).

Table 3: Based Aircraft by Airport in 2000

City	Airport Name	Based Aircraft
Hillsboro	**Portland-Hillsboro**	**355**
Aurora	Aurora State	353
Medford	Rogue Valley Intl	175
Troutdale	Portland-Troutdale	171
Eugene	Mahlon Sweet Field	160
Klamath Falls	Klamath Falls Regional	140
Independence	Independence State	137
Scappoose	Scappoose Industrial	130
Corvallis	Corvallis Municipal	123
Bend	Bend Municipal	120

Source: State of Oregon Department of Aviation Land Use Compatibility Guidebook, 2003

The annual number of operations at the Portland-Hillsboro Airport has generally increased since the early 1980's. The number of operations peaked in 2000 (Table 4).

Table 4: Portland-Hillsboro Airport Activity for Select Years

Year	Total Operations
2002	223,751
2000	244,531
1998	223,724
1996	207,778
1994	206,374
1992	199,433
1990	211,609
1988	188,566
1986	177,214
1984	139,252

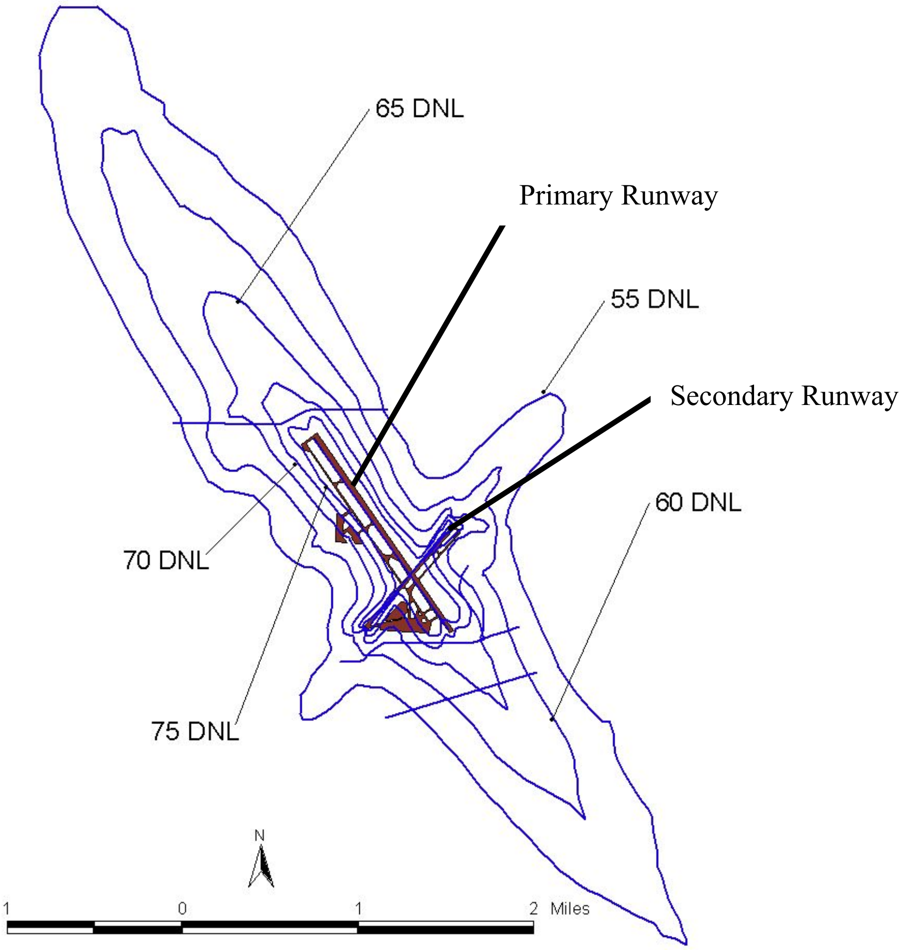
Source: Port of Portland, FAA Tower Reports, 2002

The airport has two runways. Runway 12/30 (primary runway) is 6,600 feet long, and Runway 2/20 is 4,050 feet long (secondary runway). Due to weather conditions, about 90 percent of aircraft arrive from the north, and depart to the south. Because departing aircraft creates more than twice the amount of noise as an arriving aircraft, the areas to the southeast of the airport is the area most affected by aircraft noise.

To reduce noise impacts to areas west of the airport, the 1993 *Hillsboro Airport Compatibility Study* recommended restricting the use of the secondary runway to "those times when dictated by specific wind conditions for reasons of flight safety." Flight patterns on the secondary runway (Runway 2/20) take aircraft over more densely populated areas. A successful noise management program can be achieved by avoiding unnecessary residential overflights. Limiting operations on this runway reduces noise impacts to those areas. By limiting the number of operations on the secondary runway, the number of operations on the primary runway increased and extended the noise contours out to cover a larger area. The shifting of most operations to the primary runway (Runway 12/30) has resulted in noise contours extending out beyond where they would have otherwise been if flights were not restricted, as recommended by the 1993 study (*Hillsboro Airport Compatibility Study*, 1993). The elongated nature of the airport's noise contours is illustrated in Figure 3.

Aircraft noise has become an increasing problem with people living near the airport. Recent development in the area has focused near the airport. A survey conducted by Riley Research Associates for the Port of Portland in 2002 concluded in an unaided awareness (first thing to come to mind) question that ten percent of survey respondents associated the airport with noise. When the ten percent who mentioned noise were asked to rate their level of annoyance (on a one-to-ten sale, where ten means extremely annoying), the mean level of annoyance was 5.64. The annoyance ratings were represented by three distinct groups: low annoyance ratings of one to three (29%), moderate annoyance ratings of four to seven (38%), and high annoyance ratings of eight to ten (33%). A map illustrating the geographic location of those who associated the airport with noise shows concentrations around the southeast portion of Hillsboro. The rating of the airport as an asset to Washington County was a mean of 7.13 on the same type of scale. The rating of the airport as an asset to Hillsboro was slightly higher at 7.43 (Riley Research Associates, 2002).

Figure 3: Noise Contours for the Portland-Hillsboro Airport



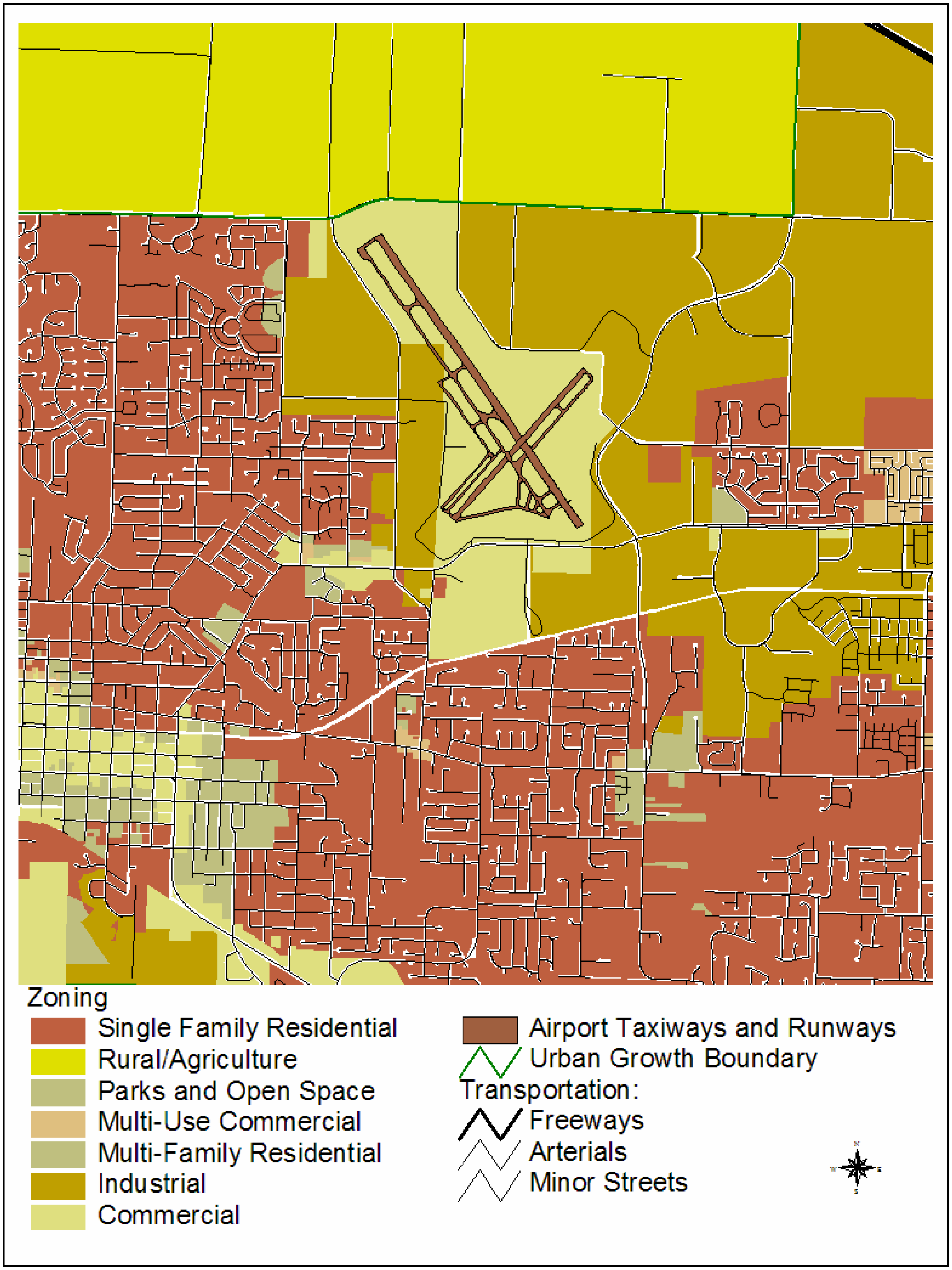
Noise Contour Source: Port of Portland, Aviation Planning and Development Department

Aircraft operators are encouraged to help maintain a good neighbor relationship with surrounding communities by following the recommended noise abatement procedures in the *Fly Neighborly* guidebook. This guidebook outlines recommended flight path procedures for aircraft departing or arriving at the Portland-Hillsboro Airport; however, safety always supersedes noise abatement patterns, and the procedures described in the guide are not intended to preempt the responsibilities of the pilot in command for aircraft operation (Port of Portland, 2002).

As outlined in the introduction, most land around the airport is zoned residential, which presents with airport activities. Zoning near the airport is depicted in Figure 4.

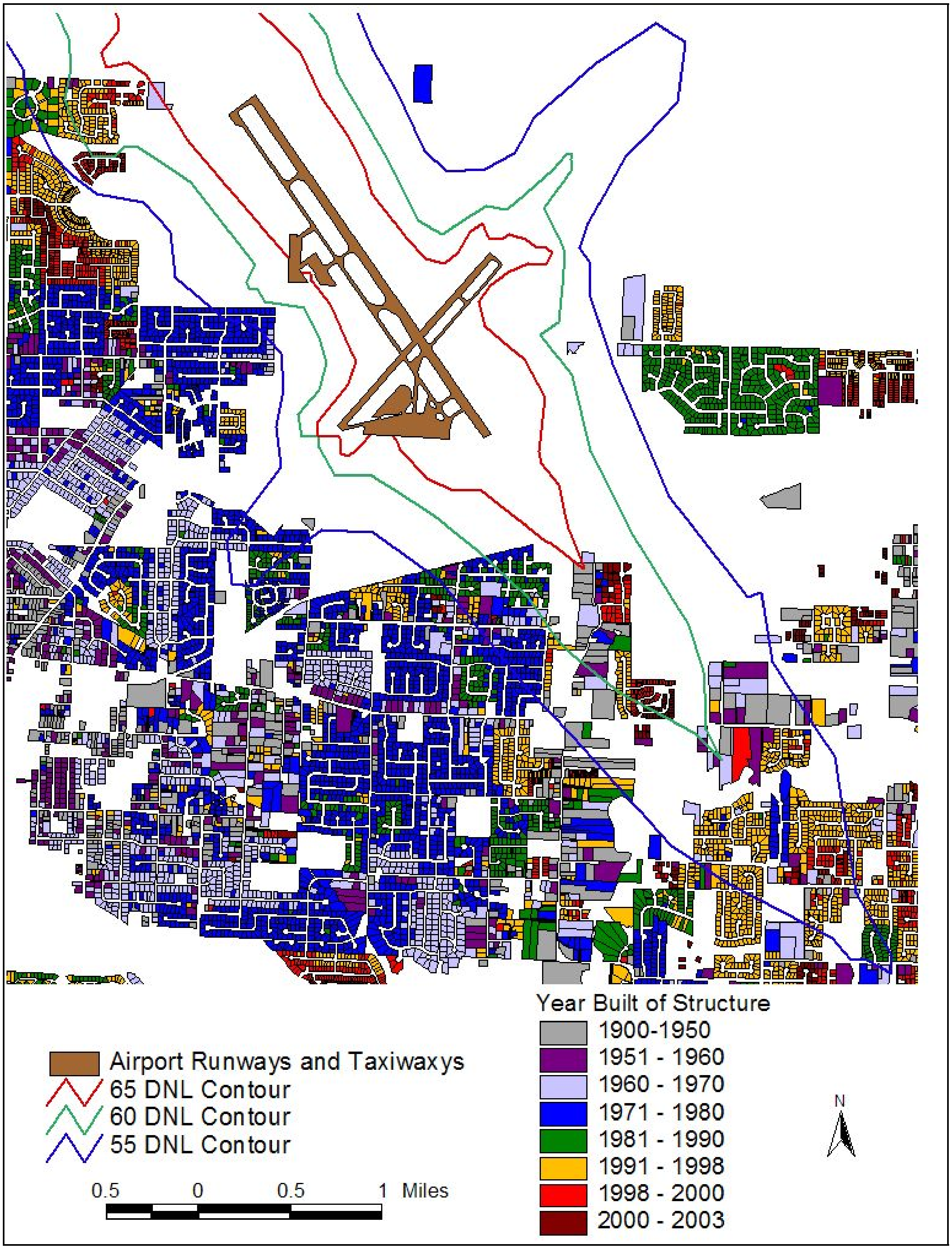
As described in the introduction and illustrated in Figure 5, with the area to the north as an exception, the land use surrounding the Hillsboro Airport is mostly developed or is in the process of becoming developed, where development is allowed. Extensive residential subdivisions were developed in the 1970's to the south and west of the airport, and recently there has been extensive development to the south and southeast of the airport.

Figure 4: Zoning Near the Portland-Hillsboro Airport



Data Source: Metro RLIS (May, 2003 update)

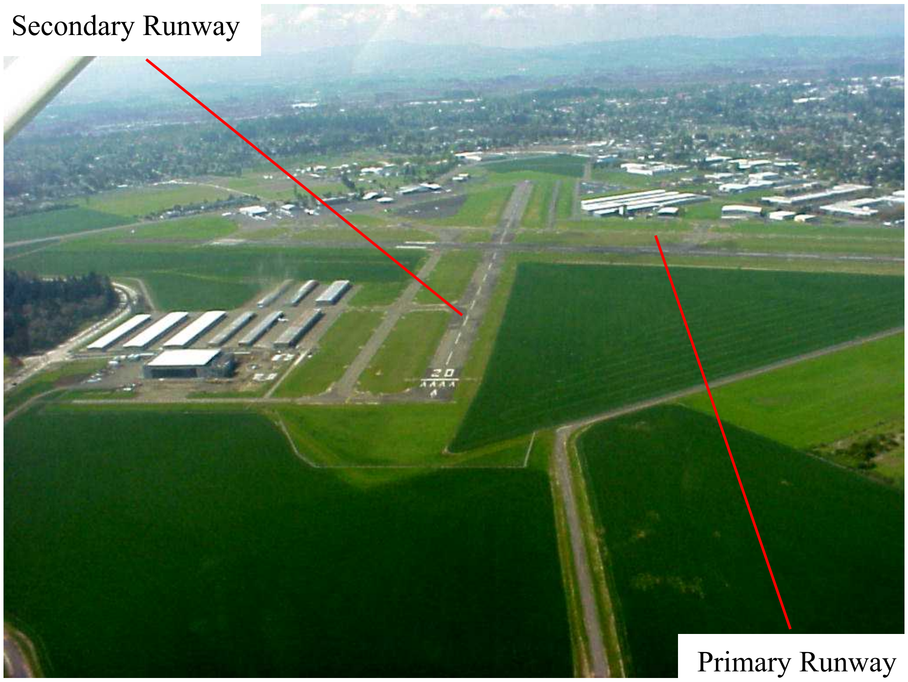
Figure 5: Year-Built of Single Family Residential Structures



Noise Contour Source: Port of Portland, Aviation Planning and Development Department
Other Data: Metro RLIS (May, 2003 update)

Picture 1 through Picture 5 illustrate the areas near the airport and underneath the flight path. Notice the new development near the runways and flight path in Picture 2, 4, and 5.

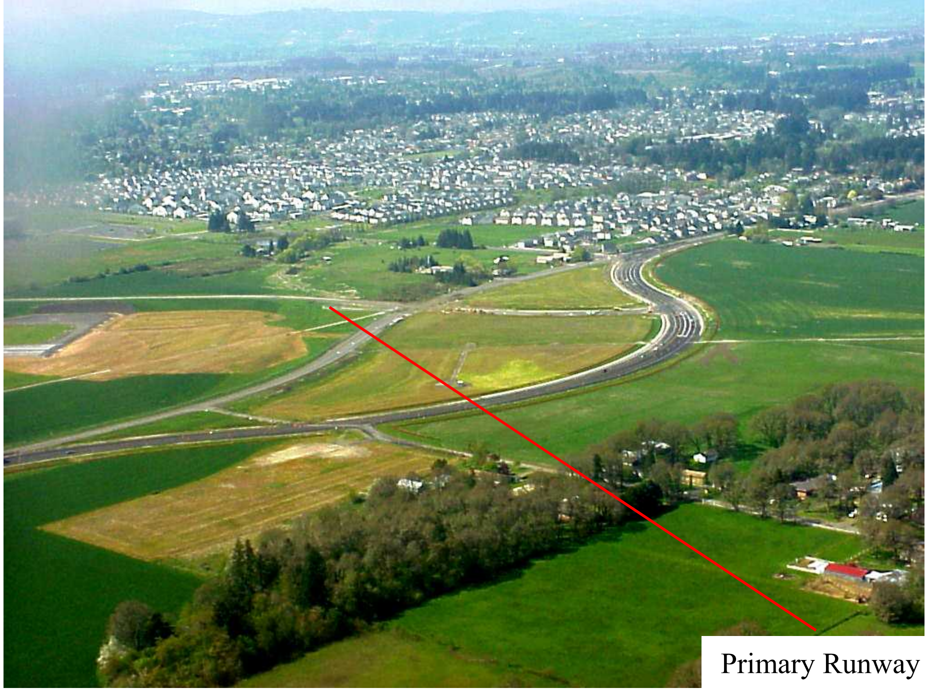
Picture 1: Secondary Runway Flight Approach Path (View to SE)



Picture 2: Newer Development Near Primary Runway (View to NE)

Picture 3: Area Near Primary Runway (View to SE)

Picture 4: Newer Development Near Primary Runway (View to Southwest)

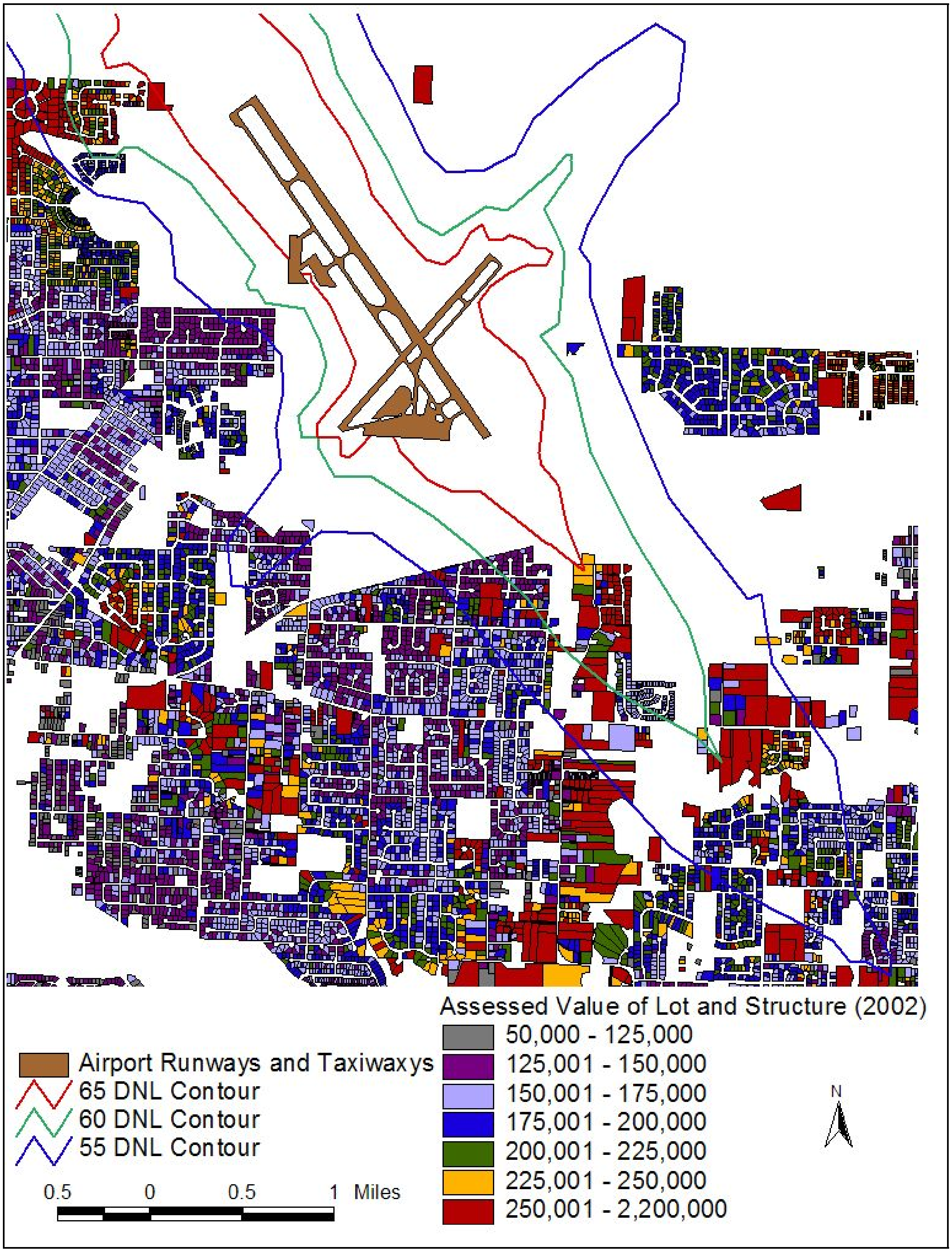


Picture 5: Newer Development Near Primary Runway (View to Northwest)

Picture 1 through 5 Source: Port of Portland, General Aviation Department

Figure 6 illustrates the assessed value of single-family properties near the airport. The assessed values are for 2002.

Figure 6: Assessed Value of Single Family Taxlots near the Portland-Hillsboro Airport



Data Source: Metro RLIS (May, 2003 update)

LITERATURE REVIEW

The presence of aircraft noise is one of many considerations the consumer must evaluate in buying or selling a residence. Researchers have been careful to consider other effects on sale prices and to normalize their influences in research studies. Although there are many factors that must be considered when evaluating home values, nearly all research conducted in this area found negative effects from aviation noise. Given differences in statistical methods, samples, time periods, and urban locations, empirical studies have not produced a singular value for the effects of airport noise on property values. With the number of various noise measurement methods available, no single standard methodology exists, adding to the complexity of comparing previous studies. In the context of various methods, consistent themes and correlations emerge. In general, studies have shown that airport noise has a negative impact on residential property values. This section reports on those studies.

Some have speculated that the convenience and economic revenues from an airport serve to offset any diminution in value; however, nothing in the body of published literature supports this notion (Bell, 1994). Approximately six million Americans currently reside on 900,000 acres of land exposed to levels of aircraft noise that creates a significant annoyance for residents. Over 600,000 Americans reside in areas that are severely impacted by aircraft noise (DNL 55+) (Bell, 2001). Despite the magnitude of noise problems, no single or universal criterion defines a “noisy” airport and there is no preferred methodology to study the problem (Booz-Allen & Hamilton, 1994). Additionally, there are over 200 types of variables that impact real estate values, such as the presence and size of a garage, air conditioning, and heating, so each study uses a different combination of conditions (Bell, 1997).

Airports may depress residential property values in two ways. First, the airport’s operations may depress property values from the *proximity to an airport’s runway* below the level real estate markets would produce if the airport did not exist. Therefore, if a single-family residence located in the proximity to an airport were physically transported to an identical location on an identical lot in a community of identical status and prestige but elsewhere in the region, its value would increase (Lane, 1994). The amount of the increase represents the depression in real estate value caused by the proximity to the airport.

A second way in which an airport may impact the value of real estate is the variation in value among properties caused by their *proximity to the airport's flight paths* for arriving and departing aircraft. This phenomenon is usually referred to as the "shadow effect", the noise pollution, visual pollution, possible air quality pollution, and the degraded environment for human habitat caused by living under low flying aircraft (Lane, 1994). While tremendous economic benefits and revenue clearly are associated with a large airport, studies conclude that those under or nearby the flight path tend to suffer a net negative impact (Bell, 1997).

Most studies of direct adverse impacts of airports have concentrated on measuring noise impacts on property values and proximity to the airport's flight paths as opposed to proximity near an airport. These studies employ a cross-section of property value data along with information on characteristics of housing and some measure of aircraft noise exposure. The most commonly used noise measure in published literature is the Noise Exposure Forecast (NEF). The NEF is the total noise exposure produced at a given point may be viewed as the sum of noise levels produced by different aircraft flying different flight paths. When summed on an energy basis over all aircraft types and flight paths, noise exposure is a function of the average perceived noise level, time of day, and number of operations (Bell, 1997). The primary noise criterion to describe the existing noise environment is the Decibel Noise Level (DNL) a noise measure that other published studies have examined in place of NEF.

Early studies used census data as a primary data resource to estimate the impacts of airport noise on residential property values. Aircraft noise impacting residential properties began in the 1960's with suburbanization and airport expansion. Table 5 summarizes the impact to property values for aircraft noise studies in 1960 and 1970 at several major airports.

Table 5: Summary Empirical Damage Estimate Studies for Aircraft Noise and Property Values in 1960 and 1970

Study Area (Year, Mean Property Value)	Range of Noise Levels	NDI-NEF Estimate* (Percent)
New York City (1960, $16,656)	55-75	1.9%
Los Angeles (1960, $19,772)	55-75	1.8%
Dallas (1960, $18,011)	55-75	2.3%
Minneapolis (1967, $19,683)	55-85	0.6%
San Francisco (1970, $27,600)	60-80	1.5%
San Jose (1970, $21,000)	60-80	0.7%
Boston (1970, $13,000)	60-80	0.6%
Toronto (1970, $32,500)	55-70	0.9%
Dallas (1970, $22,000)	55-80	0.6%
Washington D.C. (1970, $32,725)	55-70	1.0%

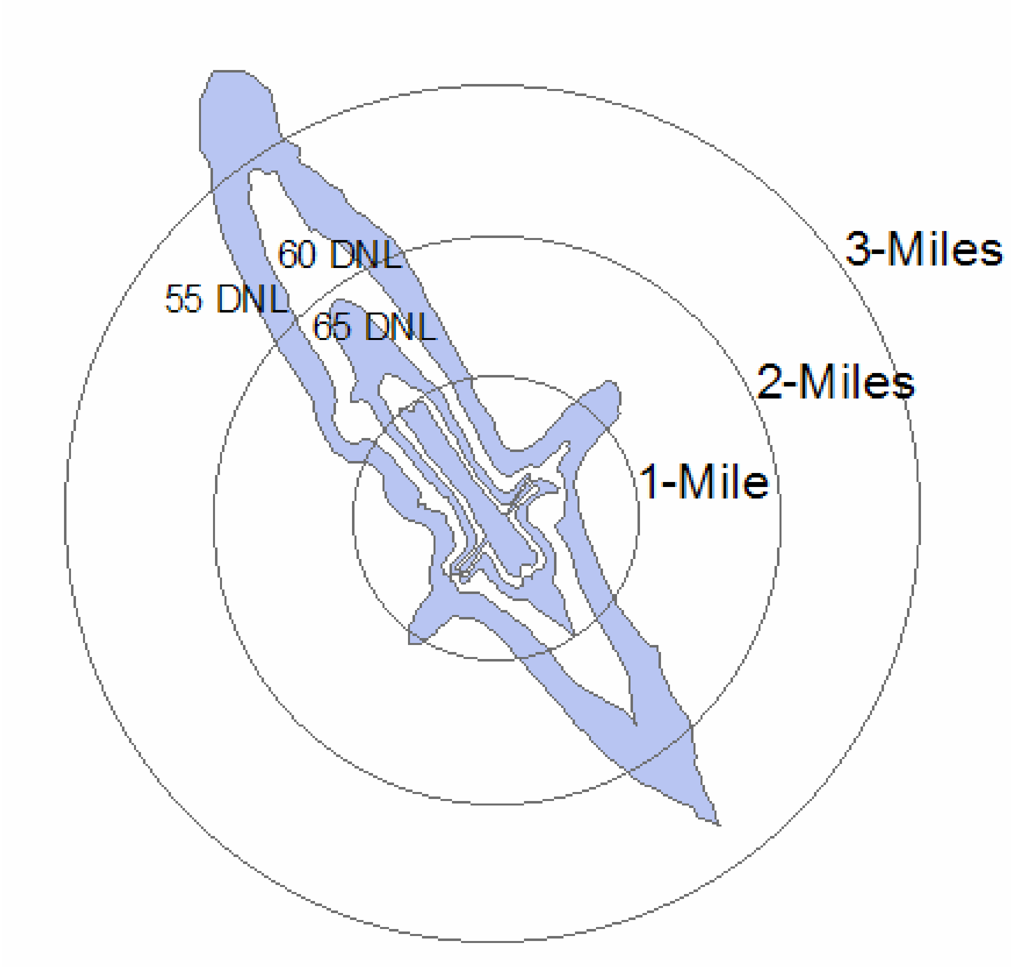
Source: Nelson (1979)
* NDI = Noise Depreciation Index. The NDI-NEF is the percentage decrease in a given property value per unit increase in the DNL
Source: Aviation Noise Effects (FAA Document, 1985)

Gautrin (1961) was one of the first to research the effects of airport noise on property values. Gautrin examined the fall in price as a function of the valuation of transportation savings and the valuation of noise for Gatwick Airport in London. No effect on residential land values was ascertained, but the author accounted for the non-significance of the results mainly as a function of the small sample size, dissimilar areas, and the fact that variance within an area was greater than between areas (Gautrin, 1961). In an additional paper, Gautrin surveyed real estate agents and reported that if noise were eliminated the agents thought that prices of houses would increase on average 10 percent.

Nelson (1979) addressed the noise versus accessibility problem based on the elongated shape of noise contours and sampling within limited areas with more or less the same degree of separation. Nelson chose two similar neighborhoods with equal access to the airport, but with different noise environments. With the noise variable in the hedonic function, the effects of noise were determined. Other studies have studied access to major airports. In particular, Tompkins (1998) used a straight-line distance to the airport as a measure of accessibility. Tompkins concluded that the effect of accessibility was greater for certain properties, so the net effect of the airport on property values was positive for some properties without accounting for noise.

The purpose of this study is to isolate the effect of noise on property values. Many studies exploit the elongated nature of noise contours and select a sample area that holds accessibility constant and noise levels to vary. Figure 7 below illustrates noise contours and proximity to an imaginary airport. Note that some properties can have a high degree of accessibility to the airport, but a low noise level. In this example, areas over 3 miles from the intersection of the airport runways are still affected by airport noise, but are not as accessible as some other areas closer to the airport that are not affected by airport noise. Therefore, the correlation between noise and access may not be high.

Figure 7: Noise Contours and Proximity to Airport



One of the most important published studies concerning airports and property values was a report prepared for the FAA entitled *The Effect of Airport Noise on Housing Values: A Summary Report* (1994). The FAA was clearly concerned with the potential effects of airport noise and property values. The results of the report indicated a consistent negative impact on residential property market values located near the airport and/or underneath the flight track. This report found that the impact on property values of airport noise varied from negligible amounts ($627 for housing units around Baltimore-Washington International Airport) to significant ($60,800 for moderately priced housing units around Los Angeles International Airport) (Booz-Allen & Hamilton, 1994). The study concluded that entry-level homes are impacted less as compared to moderately priced homes, and the loss in market value of low priced homes is generally minimal. The study also shows that the loss to moderately priced homes is as high as 19 percent. Finally, it was concluded the reduction in value of a high priced home would be approximately 2.5 times that of a moderately priced home (Booz-Allen & Hamilton, 1994). Because of the federal sponsorship of the FAA study, many studies have used the results of this study, such as the 1.33 percent estimate in diminution of property value per decibel, as a calculation for other studies.

The conclusions in the FAA study are fairly consistent with a variety of other published studies. Nelson (1979) concluded that an increase of NEF 5 over threshold noise levels would decrease the market value by 2.5 percent. Abelson (1979) concluded that a loss in property value of 0.67 percent per NEF and refers to other studies with losses of 1 percent or more per NEF. Additional insights are added by a study that indicates that a one-unit increase in NEF results in a diminution in value of 0.65 percent (Uyeno, 1993). Frankel concluded that a loss of market value ranging from 1.2 percent of low-impact properties to 21.5 percent for severely impacted properties (Frankel, 1991). In a report to the Orange County Board of Supervisors, Randall Bell concluded that the impact on single family residences near Los Angeles International, Ontario and John Wayne airports ranged from –15.0 to –42.6 percent, with an average of –27.4 percent (Bell, 1997). Nelson surveyed the results from 10 earlier studies covering 11 airports for the period between 1967-1976. The percentage decrease in property values per decibel ranged from 0.29 percent for Cleveland to 0.74 percent for San Diego (Nelson, 1985). Nelson also concluded in a separate case study of Atlanta Hartsfield International Airport a property depreciation of 0.67 percent per decibel (Nelson, 1985).

A study prepared for the Port of Seattle in 1994 examined noise effects by comparing the assessed values of 32 residences located within the Seattle-Tacoma International "Noise Remedy Area" boundary. The study compared 16 residences that were within the Noise Remedy Area and 16 other residences that were outside the Noise Remedy Area boundary (Shapiro, 1994). The study incorporated variables such as the area of the lot, the size of the house, the number of bedrooms and bathrooms, and the city in which the house was located. The study concluded that neither the existence nor the magnitude of any general effect on rates of appreciation of property values from airport noise was demonstrated.

An additional study on noise impacts in the Seattle area in 1994 funded by a grant from the State of Washington found that the proposed expansion of Seattle-Tacoma International Airport would cost five nearby cities $500 million in total property values and $22 million in real estate tax revenue. This study also found based on empirical evidence that a housing unit in the immediate vicinity of the airport would sell for 10.1 percent more if it were located elsewhere. By accessing property tax revenue and the price and location of homes, Lane (1994) was able to estimate the effects of airport noise on property tax revenue. Lane concluded that all things remaining equal, the value of a house and lot increases by about 3.4 percent for every quarter of a mile the house is farther way from being directly underneath the flight track of the airport. The study also concluded that the value of a single family residential home increases by about $17,784 for every quarter a mile it is farther away from being directly underneath a flight track. This study concluded that the airport's most adverse impacts occur in areas immediately surrounding the airport (Lane, 1994).

In an economic analysis based on empirical evidence of a conversion of a former military base to a commercial airport in Orange County, California, the impact of noise was determined to reduce the actual market value of real estate owned by residents and businesses in Orange County by $1.1 billion to $3.5 billion. This study was similar to

Lane's Seattle study (1994), which estimated the effects of noise on property tax revenue. The high estimate of $3.5 billion is more than double the cost of estimated cost to convert the airport to commercial use. The loss in market value was estimated to be $11 to $35 million in annual loss of property tax revenue (Bales, 2002).

A hedonic analysis of residential home prices in Austin, Texas provided a comprehensive analysis at the costs and benefits of the closure of a commercial airport and the conversion a military base to a commercial airport. The findings indicated that house prices near the old airport changed little with early announcement of the new airport, but changed more with the groundbreaking than with the final switch to the new airport. This finding suggests that homeowners expected airport noise and adjust to the relocation of the airport before the aircraft noise actually began (Konda, 2002). Additionally, estimates from the old airport indicate that the infrastructure development remains an amenity even after the airport is removed, causing a net gain to neighbors of the old airport. A summary of certain studies cited in this section is in Table 6 below.

Table 6: Summary of Previous Literature

Author	Location	Year Studied	Unit of Measurement	Examples of Variables (Hedonic Price Model)	Findings
Bales (2002)	El Toro, CA	2002	Decibel and DNL	Property tax rates, assessed value, location (city), distance to airport and flight tracks	Estimated decrease property tax revenue based on FAA noise data (Booz-Allen)
Booz-Allen (1994)	LA, Baltimore, NY	1994	Decibel and DNL	House size, age, number of floors, access to employment, city center, zoning	1.33% diminution of value per decibel
Lane (1994)	Seattle	1994	Distance from Airport	Lot size, structure size, number of bedrooms and baths, city location	Home values increase by $17,000 for every .01 mi from airport
Kranser (1997)	Seattle	1994	Distance from airport	Condition of home, number of bedrooms and baths, presence of air conditioning, access to	Value increases by 3.4% for every 0.25 mi from airport

Author	Location	Year Studied	Unit of Measurement	Examples of Variables (Hedonic Price Model)	Findings
				jobs	
Nelson (1985)	Atlanta	1985	Decibels	Year sold, square feet, bathrooms, basement, air-conditioning, rooms, percent minority, ownership type	A decrease of .64% in sale prices with a one unit increase in dB
Crowley (1973)	Toronto	1973	Distance to airport Compared similar neighborhoods	Population density, age of housing, transportation infrastructure, access to employment, percent minority	Mean price of airport area was consistently lower than similar neighborhoods
Nelson (1979)	SF, St. Louis, Cleveland, San Diego	1970	NEF	Number of rooms, percent black population, built before 1939, distance to airport, percent owner occupied	Consistently negative values, ranging from 0.6% to 2.3% per NEF

Please see References section for sources.

The early period of travel by commercial jet was associated with a transitional period of adjustment in residential housing markets that had essentially ended by the late 1960s. Additionally, with technology and noise abatement measures, the impact of airport noise has declined since earlier studies. Therefore, it is expected that studies older than a decade ago would yield different results. This time span encompasses a number of major airport expansions, the introduction of jets, and a general growth in aviation activity.

Various studies indicate that there is a correlation between noise levels, as measured by noise contours, and the diminution in value. More expensive homes tend to be impacted more than less expensive homes. While published reports in this review solely evaluate property near large commercial airports, there have been no published studies completed for general aviation airports such as the Portland-Hillsboro Airport; however, because cited literature concludes that the noise level, in NEF or DNL, is a key variable in determining a diminution in value of residential properties, the type of airport (commercial or general aviation) should not be a key variable since a home located in the 55 DNL contour for a commercial airport and a home located in the 55 DNL contour for a general aviation airport have the same average noise level. Additionally, the number of flights is less important than the loudness and variability of the loudness of single events because the noise level in DNL is based on the average noise level. Several loud flights could be just as loud as many passing flights. It is therefore hypothesized that the results of this analysis for the Portland-Hillsboro Airport will correlate with the results of the literature cited in this section. In other words, it is expected that aircraft noise does cause a diminution in value of property affected by airport noise; however, for basis of research, the null hypothesis will be that there is no significant difference in sale prices.

HEDONIC PRICE THEORY

Hedonic analysis is the most common method for estimating the effects of numerous amenities and disamenities on the value of residential housing. Hedonic models exploit the differentiation that exists in housing markets in terms of locational attributes. It is rare that two residential properties will be identical in all respects, except for the aircraft noise pollutant in question. In order to isolate a given hedonic price, it is necessary to control statistically for other influences on property values.

Each house and lot represents a unique combination of characteristics so the decision to purchase a given property is complex. The price a buyer is willing to pay depends on location, attributes of the neighborhood and community, local taxes, and local provided services. Since these characteristics are sold as a package, it is difficult to infer from one or two sales the incremental effect of one characteristic or attribute on the final selling price of a dwelling. However, if characteristics are provided in various combinations of selected attributes, it is possible to estimate a hedonic price relationship that gives the price of any variable as a function of quantities of various characteristics. An example of the functional form of a hedonic price model is:

$$\textbf{Selling Price}_i = \mathbf{f(H_i, E_i, S_i)}$$

The selling price of a home (i) is dependent on the home's attributes (H_i), the environmental attributes of the area around the home (E_i) and the socioeconomic characteristics of the neighborhood (S_i). The price of any one of these vectors will be determined by the particular combination of characteristics it displays.

Attributes of every property can be described by the qualities or characteristics of its structure, environs and location. Therefore, any house could be described by a vector, effectively a list of different quantities of each characteristic of the property. Properties possessing larger quantities of good qualities are expected to command higher prices and those with larger quantities of bad qualities are expected to command lower prices. This function is known as the hedonic price function. It is possible to estimate the hedonic price function by observing the selling prices of properties in a market. If there is enough information on the selling prices of properties exhibiting different characteristics, then it is possible tease out how much each individual characteristic influences the total price of a property. The principle underlying the analysis is that the ‘airport factor’ can be deduced by accurately determining the difference in value of two essentially identical dwellings, one close to the airport, while the other is not (Shapiro and Associates, 1994).

Measurement of the economic value of quietude has traditionally focused on the effect of significant noise exposure on residential property values. Early studies employed aggregate census tract and census block data. Recent studies have used sales data for individual properties. The next generation of hedonic price studies will use geographical information system (GIS) methods, which has already been applied to noise generated by road traffic.

Despite frequent reliance upon hedonic analysis in property value estimation, it is not an exact science. Constructing a regression model that reflects all of the impacts of property value and sale price is impossible. There are a number of unique factors influencing sale prices to a particular area. The availability of data for a given study determines what factors can be included. For the best estimate of property values, all variables should be incorporated into the regression that would influence a sale price, but lack of data prevents this. Variables that are difficult to include are the condition of the home, the presence of air conditioning, the presence and number of fireplaces, and the finished products inside the home that may increase the value.

METHODOLOGY

STUDY PURPOSE

The purpose of the analysis is twofold:

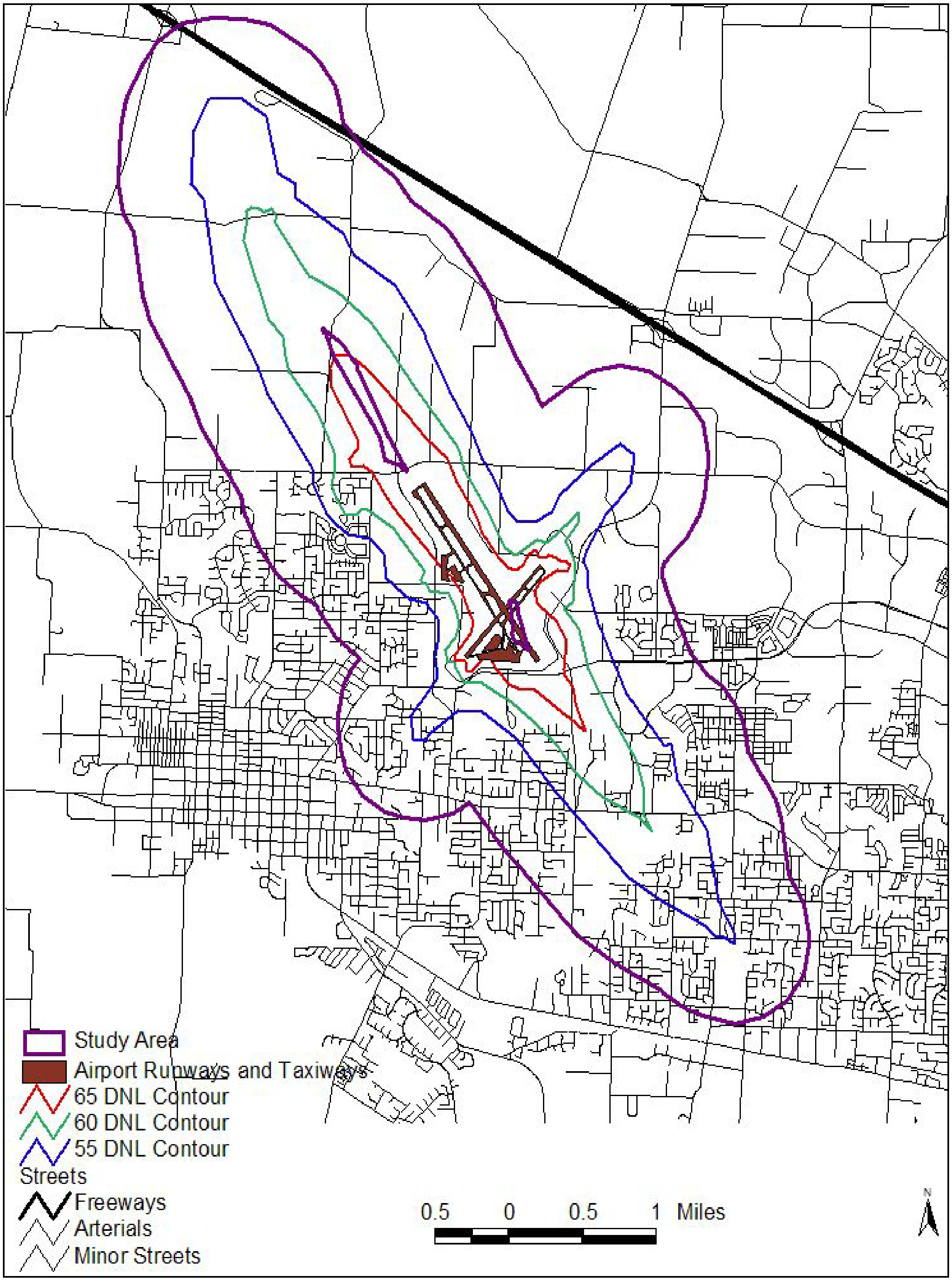
- To determine if there is a significant difference between single-family residential property sale values in proximity to the airport (Proximity to Airport's Runways), and;
- To determine if there is a significant difference between single-family residential property sale values in proximity to the airport's 55 DNL contour or higher (Proximity to Airport's Flight Tracks).

Study results will estimate the percent decrease in property values with increasing distance to the airport and increasing distance from the airport's flight tracks. The results will also conclude which has more of an effect on housing values: the proximity to airport or proximity to the airport's flight tracks.

STUDY AREA

A study area was selected to capture the variety of properties in vicinity of the airport and its flight tracks, but not to extend far beyond properties that were not in proximity of the airport or the airport's flight tracks. Therefore, the study area encompasses an area entirely within the City of Hillsboro. The study area was restricted to the area within the 55 DNL noise contour of the Portland-Hillsboro Airport and a 0.5- mile buffer from the 55 DNL contour. The half-mile buffer was created outside of the 55 DNL noise contour to allow for a control group of housing in the sample. The null hypothesis tested was that airport operations have no effect on residential sale prices with decreasing distance from the airport and the airport's flight tracks. Figure 8 below illustrates the study area. The methodology to select these taxlots is explained in more detail in the process section below.

Figure 8: Study Area



Sources: Metro RLIS (2003), Port of Portland Aviation Planning and Development Department

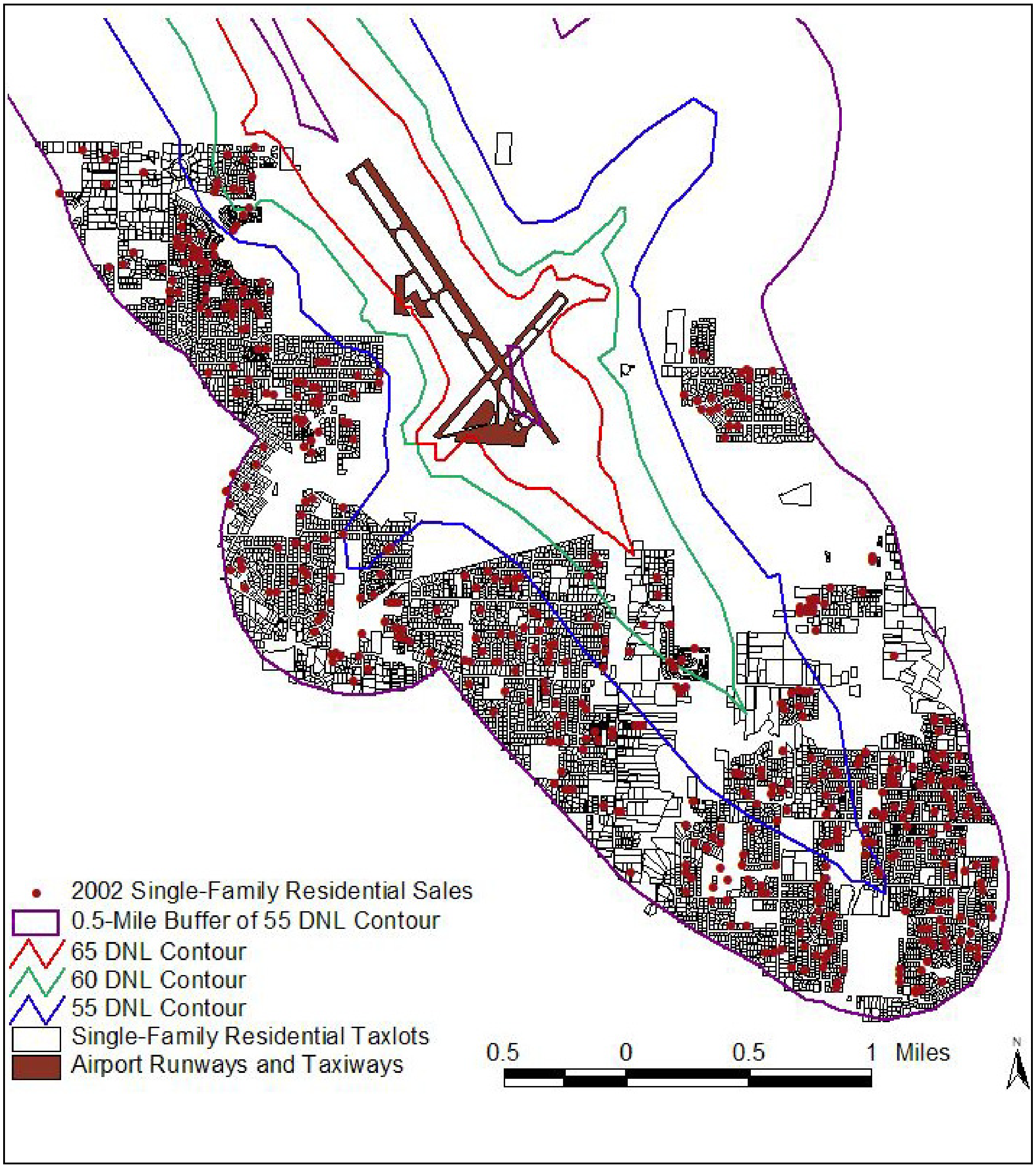
DATA

Data used for analysis and referenced in this study was acquired from Regional Land Information System (RLIS) (2002). This database is maintained and updated by Metro, the regional government for three Oregon counties located in the Portland metropolitan area. RLIS data provided sale prices, square footage of structures, lot size, year built, and sale date of property. The Washington County Assessor's Office provided information for the number of bedrooms and bathrooms for each structure. The dollar amount of actual sales data in Washington County is a matter of public record. This source also contained the same data as RLIS and was used to check for accuracy. Traffic count data was obtained from the City of Hillsboro to determine the most heavily used roads. Noise contours (1995) for the Portland-Hillsboro Airport were obtained from the Port of Portland, the owner of the Portland-Hillsboro Airport. Noise levels are 1995 conditions, measured and calculated as part of the 1996 *Portland-Hillsboro Airport Master Plan*, the most recent master plan for the Portland-Hillsboro Airport. The 1995 noise contour data is the most recent noise data for the airport, but the contours have not likely changed significantly. The noise contour maps illustrate the 55, 60, 65, 70, and 75 DNL contours. With help of GIS, the data was used to derive information about the location of properties with respect to the noise contours and in relation to other features. This is explained in more detail below.

PROCESS

Using GIS, all single-family residential zoned taxlots with a sale date in 2002 were identified. Parcels with property values less than $50,000 were determined to be uninhabitable and were excluded from the sample. A parcel of land with a habitable structure in the area valued at $50,000 or less is highly unlikely for this area. As previously described in the literature review section, it is the sale price and not the assessed value that is hypothesized to affect residential property values near the airport. Therefore, a sale date for one year was necessary for analysis because the noise contour data is based on one year of noise data. Next, using Metro's RLIS database (2002), all single family residences without data in all of the following categories were excluded: area of taxlot, land value, building value, total value, building square feet, construction date of structure, and sale price. There are a total of 7,192 single-family residential properties in the study area. The total number of sites studied in this report defined by using the above process was 495 (number of homes sold in 2002 in study area), representing 6.8 percent of the total study area. A total of 42 sites were excluded due to incomplete data. Figure 9 below illustrates the location of the 495 studied properties in this study.

Figure 9: Location of Properties Studied



Data Source: Metro RLIS (May, 2003 update)

MODELS FOR PROXIMITY TO AIRPORT RUNWAYS

Using a statistical package (SPSS, Version 10.0), a regression analysis was performed to determine a regression equation for sale price of areas near the airport. The value of single-family residential properties was estimated using the following regression model:

Model 1:

$$\mathbf{(Y) = \alpha + b_1X_1 + b_2\,X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + u}$$

Where:

Y = 2002 Sale Price of Lot and Structure (dollars)

α = Constant

X_1 = Area of Lot (square feet)

X_2 = Structure Size (square feet)

X_3 = Age of Structure (years)

X_4 = Number of Bedrooms

X_5 = Number of Bathrooms

X_6 = Distance to Light Rail Station (miles) (straight line)

X_7 = Distance to Downtown Hillsboro (miles) (straight line)

X_8 = Network Distance to Highway 26 (miles)

X_9 = Location Adjacent to Busy Street

X_{10} = Noise Level (DNL)

X_{11} = Distance to Airport Runway (miles)

u = Stochastic Error Term

Explanation of Variables

The following describes the variables used in the hedonic equation in more detail:

- **Area of Lot:** The square footage of the single-family residential zoned property (taxlot). Data was obtained from Metro’s RLIS (2002) and/or Washington County’s Assessors Office.

- **Structure Size:** The total square footage of the structure located on the property. Data was obtained from Metro's RLIS and/or Washington County's Assessors Office.

- **Age of Structure:** The age of the structure on the property relative to 2002. For instance, a structure built in 1999 would have an age of 3 years. Data was obtained from Metro's RLIS database.

- **Number of Bedrooms:** Total number of bedrooms in the structure, identified by Taxlot ID number for each property. Bedrooms are defined as enclosed rooms with a closet and operable window. Data was obtained from the Washington County Assessors Office.

- **Number of Bathrooms:** Total number of full bathrooms in the structure, identified by Taxlot ID number for each property. Full bathrooms consist of a shower and/or bathtub, a toilet, and a sink. Data was obtained from Washington County Assessors Office.

- **Distance to Light Rail Station:** The straight-line distance in tenths of a mile from the center of the property to the nearest MAX light rail station. MAX is the regional light rail system for the Portland metropolitan area. The MAX line (Blue Line) to Hillsboro was completed and opened in 1998. This line connects downtown Hillsboro with downtown Portland and areas to the east of downtown Portland. The Blue Line terminates in Downtown Hillsboro at the Hatfield Government Center. Straight-line distance was used instead of network distance because there are often routes other than streets to walk to and from a light rail station. Distance was calculated using GIS.

- **Distance to Downtown Hillsboro:** The straight-line distance in tenths of a mile from the center of the property to Downtown Hillsboro to measure accessibility. Because Hillsboro is the county seat for Washington County, downtown Hillsboro is a large employment and retail area. Distance was calculated using GIS.

- **Network Distance to Highway 26:** The network distance from the center of the property to the Cornelius Pass intersection of Highway 26, the closest interchange to the study area. This variable estimates accessibility to Highway 26, the main route to the downtown Portland and the east side of the Portland metropolitan area. Distance was calculated using GIS.

- **Location Adjacent to Major Street**: A dummy variable was assigned to properties located on or adjacent to a busy street, which may be affected by excess noise from vehicular traffic. For this study, busy streets were defined as streets with average daily traffic (ADT) of more than 5,000 vehicles/day. Traffic count data for 2002 was obtained from the City of Hillsboro. A dummy variable was assigned instead of actual traffic count data for each property because ADT was not available for all streets in the city. Only major streets are included in the City's traffic count data. The 5,000 vehicles/day threshold represents the top 10 percent of busiest streets in the defined study area. Streets that met the criterion of at least 5,000 vehicles/day and located in the defined study area were:
    - E Main Street
    - NE 25th Ave
    - NE 28th Ave
    - NW Evergreen Parkway
    - SE Cypress Street

- **Noise Level in DNL:** Noise level was estimated using the noise contour map by assigning an estimated noise level for each property. This map shows the noise contours for the 55, 60, 70, and 75 DNL areas. Individual properties used in this analysis were coded with a DNL noise level according to estimated noise exposure they fell into on the noise contour map. Noise levels were estimated using noise contour data provided by the Port of Portland. Distance (miles) for each studied property was calculated from the 55 DNL noise contour. Distance for each studied property from the airport's runways was also calculated.

While city services and tax structure are important in choosing a home, all properties are located within Hillsboro city limits. Therefore, a variable for city services and tax level was unnecessary. Summary statistics of the data used in all models are shown in Table 7.

Table 7: Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum	Number of Observations (=1 for Dummy Variables)
Sale Price	$192,528	$54,435	$50,000	$812,500	495
Area of Lot	7,974.1	6,154.4	2,589.9	77,728.3	495
Structure Size	1,761.80	482.1	864	3,980	495
Age	13.6	14.4	0	112	495
Bedrooms	3.33	0.65	2	7	495
Bathrooms	2.51	0.75	1	6	495
Dist to Light Rail	0.96	0.51	0.01	1.96	495
Dist to Downtown	1.98	0.83	0.31	3.37	495
Dist to Hwy 26	2.83	0.46	1.57	3.98	495
Busy Street	0.04*	0.19	0	1	35
Dist from 55 DNL	0.23	0.12	0.00	0.50	414
Dist from Runway	1.58	0.76	0.31	3.01	495

*=percent "yes" (located adjacent to a major street)

Model 2:

An interaction variable was added in Model 2 in place of the Distance to Runway variable. The description s of variables is the same as in Model 1.

$$\mathbf{Y = \alpha + b_1X_1 + b_2 X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + u}$$

Where:

Y = 2002 Sale Price of Lot and Structure (dollars)

α = Constant

X_1 = Area of Lot (square feet)

X_2 = Structure Size (square feet)

X_3 = Age of Structure (years)

X_4 = Number of Bedrooms

X_5 = Number of Bathrooms

X_6 = Distance to Light Rail Station (miles) (straight line)

X_7 = Distance to Downtown Hillsboro (miles) (straight line)

X_8 = Network Distance to Highway 26 (miles)

X_9 = Location Adjacent to Busy Street

X_{10} = Noise Level (DNL)

X_{11} = (Distance from Airport (miles)) * (Noise Level (DNL))

u = Stochastic Error Term

- **Interaction Variable:** The effect on housing value of proximity to the airport is measured through the use of two variables: a distance variable that measures distance from the airport, and an interaction variable (X_{11}) defined as airport noise level multiplied by the distance from the airport. The addition of the interaction term may improve the accuracy of the results due to the collinearity between distance and noise. Distance was calculated by using GIS.

MODELS 3 AND 4: PROXIMITY TO AIRPORT'S FLIGHT TRACKS

While proximity to an airport may play a role in sale price devaluation, the alignment of runways and the flight paths' associated noise levels are hypothesized to have a greater effect on sale price, based on cited literature in the Literature Review section. As previously described, the 55 DNL noise contour is the noise level where airport noise begins to disrupt residential properties located near an airport, as defined by the FAA, and the airport land use compatibility as defined by the State of Oregon. An important purpose of this study is not only between different noise level contours within which housing units are located, but also between a residential housing unit's distance from being directly under the flight track of approaching and departing aircraft. A distance variable (Distance from airport's 55 DNL contour) was introduced into the regression equation to explain the '*aircraft* factor'. The descriptions of the variables are the same as described above in Model 1.

Model 3:

$$\mathbf{Y = \alpha + b_1X_1 + b_2\,X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + u}$$

Where:

Y = 2002 Sale Price of Lot and Structure (dollars)

α = Constant

X_1 = Area of Lot (square feet)

X_2 = Structure Size (square feet)

X_3 = Age of Structure (years)

X_4 = Number of Bedrooms

X_5 = Number of Bathrooms

X_6 = Distance to Light Rail Station (miles) (straight line)

X_7 = Distance to Downtown Hillsboro (miles) (straight line)

X_8 = Network Distance to Highway 26 (miles)

X_9 = Location Adjacent to Busy Street

X_{10} = Noise Level (DNL)

X_{11} = Distance from Airport's 55 DNL contour (miles)

u = Stochastic Error Term

Similar to Model 2 above, an interaction term was introduced in the equation for Model 4. Since noise and distance from the airport's 55 DNL contour are closely related, the introduction of the interaction term may confirm more accurate results since the collinearity between distance and noise is reduced with the addition of the interaction term. The descriptions of variables are the same as described above in Model 1.

Model 4:

$$\mathbf{Y = \alpha + b_1X_1 + b_2\,X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + u}$$

Where:

Y = 2002 Sale Price of Lot and Structure (dollars)

α = Constant

X_1 = Area of Lot (square feet)

X_2 = Structure Size (square feet)

X_3 = Age of Structure (years)

X_4 = Number of Bedrooms

X_5 = Number of Bathrooms

X_6 = Distance to Light Rail Station (miles) (straight line)

X_7 = Distance to Downtown Hillsboro (miles) (straight line)

X_8 = Network Distance to Highway 26 (miles)

X_9 = Location Adjacent to Busy Street

X_{10} = Noise Level (DNL)

X_{11} = (Distance from Airport's 55 DNL Contour (miles)) * (Noise Level (DNL))

u = Stochastic Error Term

The effect on housing value of proximity to the airport is measured through distance variables that measure distance from the airport and an airport noise level variable (interaction variable). A negative sign on the noise coefficient in all models would indicate that airport noise has a negative impact on the market value of homes. Summary statistics for Models 3 and 4 used the same data as Models 1 and 2 and are shown in Table 4 above. Table 8 below illustrates the hypothesized signs of regression model variables.

Table 8: Hypothesized Signs of Regression Model Variables

Variable	Hypothesized Sign
Area of Lot	+
Structure Size	+
Age of Structure	-
Number of Bedrooms	+
Number of Bathrooms	+
Distance to Light Rail Station	-
Distance to Downtown Hillsboro	-
Distance to Highway 26	-

Variable	Hypothesized Sign
Location Adjacent to Busy Street	-
Noise Level	-
Distance to Runway	-
Distance to 55 DNL Contour	-

MODELS AND EMPIRICAL RESULTS

Several different functional forms have been estimated in previous studies of airport noise-property value relationship. Since not all of these forms are directly comparable and since there is no justification for favoring one form over the other, the coefficients are estimated using the linear, semi-log and double log functional forms. The linear model estimates a regression equation with a straight linear line. If some of the variables are in log form and some are not, then the model is called "semi-log". If all variables are in log form, then the model is called a "double-log", meaning, both independent and dependant variables are in log forms. Table 10 and Table 11 illustrate model results for proximity to the airport. Note in that for Model 1 in Table 9, the constant and all of the following variables are significant at the 90 % level: area of lot, structure size, age of structure, number of bedrooms, distance to light rail, distance to downtown Hillsboro, distance to Highway 26, location adjacent to a busy street, and distance to runway. Table 12 and Table 13 illustrate results for proximity to airport's flight tracks. Full results are shown in Appendix A. Not all variables had the expected sign in each model.

Table 9: Liner Results for All Models

Coefficient	Model 1	Model 2	Model 3	Model 4
Constant	132,408	154,538	115,981	112,147
	(-2.96)*	(3.19)*	(2.65)*	(2.58)*
Area of Lot	1.77	1.77	1.79	1.79
	(6.85)*	(6.87)*	(6.91)*	(6.90)*
Structure Size	83.82	83.77	85.73	85.74
	(20.95)*	(20.91)*	(21.94)*	(21.94)*

Coefficient	Model 1	Model 2	Model 3	Model 4
Age of Structure	-700.17	-698.10	-687.62	-688.1
	(-5.18)*	(-5.16)*	(-5.04)*	(-5.05)*
Number of Bedrooms	-12,295	-12,295	-12,218	-12,222
	(-4.41)*	(-4.41)*	(-4.37)*	(-4.37)*
Number of Bathrooms	-979.49	-911.9	-1,318	-1,314
	(-0.33)	(-0.31)	(-0.45)	(-0.45)
Distance to Light Rail Station	9,200	9,178	15,151	15,127
	(2.31)*	(2.30)*	(4.93)*	(4.92)*
Distance to Downtown Hillsboro	-15,806	-15,783	-3,107	-3,111
	(-2.63)*	(-2.62)*	(-1.61)	(-1.71)*
Distance to Highway 26	-23,958	-23,962	-13,592	-13,592
	(-4.30)*	(-5.16)*	(-4.31)*	(-4.30)*
Location Adjacent to Busy Street	-6,493	-6,536	-5,934	-5,935
	(-4.41)*	(-0.94)	(-0.85)	(-0.85)
Noise Level	263.05	-147.95	-25.08	44.94
	(0.35)	(-0.19)	(-0.33)	(0.59)
Distance to Runway	17,323	---	---	---
	(2.19)*	---	---	---
Interaction Term	---	319.4	---	-299.5
	---	(2.18)*	---	(-1.48)
Distance to 55 DNL	---	---	-16,498	---
	---	---	(-1.51)	---

Table 10: Model 1 Results (Proximity to Airport)

Coefficient	Linear	Semi-Log	Double-Log
Noise Level	-263.05	-0.0013	0.043
	(-0.35)	(-0.11)	(0.24)
Distance to Runway	17,323	0.022	-0.062
	(2.19)	(1.53)	(2.56)
Adjusted R^2	0.717	0.763	0.763

(T-statistics are in parentheses)

Table 11: Model 2 Results (Proximity to Airport)

Coefficient	Linear	Semi-Log	Double-Log
Noise Level	-147.95	-.0038	-0.022
	(-0.19)	(-0.805)	(-0.123)
Interaction Term	319	0.0030	0.0749
	(2.18)	(0.843)	(3.11)
Adjusted R^2	0.711	0.764	0.773

(T-statistics are in parentheses)

Table 12: Model 3 Results (Proximity to Airport's Flight Tracks)

Coefficient	Linear	Semi-Log	Double-Log
Noise Level	-25.08	-0.00055	0.0087
	(-0.33)	(-0.46)	(0.47)
Distance to 55 DNL Contour	-16,498	-0.043	-0.0115
	(-1.51)	(-2.24)	(-1.77)
Adjusted R^2	0.715	0.764	0.761

(T-statistics are in parentheses)

Table 13: Model 4 Results (Proximity to Airport's Flight Tracks)

Coefficient	Linear	Semi-Log	Double-Log
Noise Level	-44.94	-0.00039	-0.0192
	(0.59)	(-0.27)	(-0.81)
Interaction Term	-299.5	-0.00079	0.0628
	(-1.48)	(-2.21)	(2.57)
Adjusted R^2	0.715	0.764	0.763

(T-statistics are in parentheses)

DISCUSSION OF RESULTS

PROXIMITY TO AIRPORT'S RUNWAYS (MODEL 1 AND MODEL 2)

The estimated hedonic regression in the two models for proximity to the airport suggests that there is no significant relationship between airport noise and property values at the 90 percent level. The noise coefficient in for one of the functional forms implies that for a one-decibel increase in airport noise, there is approximately a $148 (linear form) reduction in property value. Since the mean sale price of homes in the study area is $197,000, a decrease of $148 per decibel is a negligible amount. Residential properties are not allowed at or beyond the 65 DNL contour. Therefore, the maximum depressed property value is $1,480, if a property had a noise value of 64 DNL. This value accounts for only 0.7% of the mean sale price. The semi-log model estimated a 0.13% reduction in property values per decibel increase, but is not statistically significant. The distance to runway coefficient in Model 1 suggests that there is an increase of about $17,300 (linear form) as distance increases by one tenth (0.1) of a mile from the airport. This value is statistically significant at the 90 percent level. The semi-log form indicates an increase of 2.2 percent per tenth of a mile as distance increases from the airport.

PROXIMITY TO AIRPORT'S FLIGHT TRACKS (MODEL 3 AND MODEL 4)

The estimated hedonic regression in the two models for proximity to the airport's flight tracks suggests that there is no significant relationship between airport noise and property values at the 90 percent level. The noise coefficient in all but one of the functional forms implies that for a one-decibel increase in airport noise, there is approximately a $25 (linear form) reduction in property value. The mean sale price of homes in the study area is $197,000. A decrease of $25 per decibel is a negligible amount. This value accounts for very low percent of the mean sale price, and the noise coefficient is not statistically significant in all cases. The distance to flight track coefficient in Model 3 suggests that there is a *decrease* of about $16,500 (linear form) as distance increases by 0.1 mile from the airport. This value is statistically not significant at the 90 percent level. The semi-log form indicates an increase of 4.4 percent per 0.1 mile as distance increases from the airport. This value is statistically significant at the 90 percent level.

The results for this study outlined above do not correlate with findings of previous studies. A key factor in the sale price of homes is the price that a buyer is willing to pay for a property. While the location and possible environmental effects of large airports such as PDX may factor into the price that a buyer is willing to pay, the location and environmental effects (noise, air pollution) of general aviation airports is normally not considered when purchasing property. Most consumers do not use general aviation airports and are likely unaware of the negative environmental effects that a general aviation airport may cause. Therefore, the presence of the airport and the effects of the airport may be unknown when a buyer purchases a property. This theory may have influenced the results in this study. While many know the location of PDX in the Portland area and the associated noise effects from the airport's operations, the Portland-Hillsboro Airport serves a smaller percentage of people and likely does not heavily influence the price a buyer is willing to pay for a property; however, as Hillsboro continues to grow with development steered towards the airport due to decreased land supply in the Portland metropolitan area, the effects of noise on property values may become an increasing problem with residents and therefore may affect sale prices of residential property near the airport and its flight tracks.

CONCLUSION

There have been a number of studies examining the relationship between airport noise and residential property values. No published research has studied noise and property values near general aviation airports. Reviewed literature indicates that the impact of noise from practically all studied airports on residential properties was universally negative on residential property market values under or near a flight corridor and near the airport's runway. While more people will likely choose to not live in a home that is impacted by airport noise than the population that would accept airport noise, the results from this study indicate that the sale prices of homes are not affected by airport operations and aircraft noise from a general aviation airport.

The hedonic pricing technique is used in this study to determine the impact that airport noise and proximity to the airport have on residential property values in the vicinity of the Portland-Hillsboro Airport in Hillsboro, Oregon. This report incorporated distance from the airport's runways and distance from the airport's flight tracks. This study concluded that sale prices of homes are not significantly affected with increased noise level, decreasing distance from the airport, and decreasing distance from the airport's flight tracks. Sale prices are statistically higher with increasing distance from the airport's runways. The findings of this report indicate that noise is not main the factor of decreasing property values with decreased distance from the airport's runways.

Prior studies indicate that the price per decibel of noise is usually between 0.4 percent to 1.1 percent (Nelson, 1980). This study indicated a decreased price with increasing noise level, but unlike other studies, the noise value per decibel coefficient is not statistically significant. Other studies concluded that the disamenity value associated with a one-decibel increase in airport noise diminished as the distance a property is located from the airport increases. This study concluded that a one-decibel increase in noise does not statistically affect the market sale value of residential properties.

Information about the impact of airports on residential property value can be valuable, especially to officials associated with airports experiencing increasing flights or expansion. Such growth may not have been anticipated at the time of purchase and the homeowner may be negatively impacted by the changes. This study does not account for future expectations, but it does provide some new information for the Port of Portland, owner and operator of the airport and for others in the area around the airport, including homeowners. This report and other airport-land use related studies may aid in broad policy decisions for noise abatement alternatives and estimates based on property value data.

FURTHER STUDY

This study forms the foundation for a future study to further explore the relationship between general aviation aircraft noise, and residential sale values near a general aviation airport. The analysis in this paper can be improved along several research avenues. First, the regression would probably benefit from the addition of additional independent variables since the price of homes is determined by many factors. Examples of possible independent variables include the number of floors, the presence of a fireplace, heater, or air-conditioning, and the presence and size of a garage. Further analysis of the Portland-Hillsboro Airport can also analyze a time period of several years to determine a trend in sale prices and compare with operations and noise levels at the airport. Additional analysis could also examine other land uses other than single-family residential.

REFERENCES

Abelson, P. “Property Prices and the Value of Amenities,” *Journal of Environmental Economics and Management* (January 5, 1979).

Aircraft Owners and Pilots Association (website) (2002). Accessed June 3, 2003 from http://www.gaservingamerica.org/index.htm

Bales, L. *Loss of Property Value and Property Tax Revenue Attributable to El Toro Airport Noise*. (El Toro Airport Review, January 2002).

Bell, Randall. “Airport Diminution in Value Study,” *The Appraisal Journal* (July, 2001).

Bell, Randall. “Airport Diminution in Value.” Report submitted to Orange County Board of Supervisors, January 1997.

Booz-Allen & Hamilton, Inc., “The Effect of Airport Noise on Housing Values: A Summary Report,” Office of Environmental and Energy, Federal Aviation Administration (September 15, 1994).

Crowley, R. “A Case Study of the Effects of an Airport on Land Values” *Journal of Transportation Economics Policy* (July, 1973).

Federal Aviation Administration. “Land Use Compatibility and Airports” United States Department of Transportation, FAA (September, 1999)

Federal Aviation Administration, Office of Environment and Energy. “Aircraft Noise: How We Measure It and Assess Its Impact,” United States Department of Transportation (1994).

Federal Aviation Administration. “Aviation Noise Effects,” (paper document), 1985.

Frankel, M. “The Impact of Airport Noise on Willingness to Pay for Residences,” *Pergamon* (April 5, 1996).

Gautrin, J. “The Economics of Aircraft Noise.” *Journal of Political Economy* (June, 1961).

Kranser, L. “The Impact of Airports on Home Values,” Accessed on March 13, 2003 at http://www.eltoroairport.org/issues/impacts.html.

Lane, T. “The Impact of Airport Operations on Land Values: A Case Study of Seattle-Tacoma International Airport,” *Journal of Transportation Economics Policy* (February, 1994).

Nelson, J. “Housing Values, Census Estimates, Disequilibrium, and the Environmental Cost of Airport Noise: A Case Study of Atlanta,” *Journal of Environmental Economics and Management* (December, 1985).

Nelson, J. “Airport Noise, Location Rent, and the Market for Residential Amenities,” *Journal of Environmental Economics and Management* (March, 1979).

Oregon Department of Aviation. “Airport Land use Compatibility Guidebook,” State of Oregon (January, 2003).

Port of Portland. “Noise Abatment Programs: HIO” (paper document) (2002).

Port of Portland. “Hillsboro Airport Master Plan, 1996: Final Report.” (October, 1996).

Port of Portland. “Hillsboro Airport Compatibility Study” (May 1993).

Riley Research Associates. “Hillsboro Airport Community Survey Executive Summary” (May 14, 2002).

Shapiro and Associates, 1994. *Sea-Tac Airport Vicinity Land Use Inventory Project* (Aviation Planning Division, Port of Seattle).

Uyeno, D. “Density of Residential Land Use and the Impact of Airport Noise,” *Journal of Transport Economics and Policy* (January, 1993).

APPENDIX A: MODEL RESULTS

MODEL 1

Coefficient	Linear	Semi-Log	Double-Log
Constant	132,408	5.12	2.88
	(-2.96)*	(63.67)*	(8.89)*
Area of Lot	1.77	0.0000039	0.19
	(6.85)*	(7.51)*	(10.59)*
Structure Size	83.82	0.00016	0.54
	(20.95)*	(22.65)*	(15.85)*
Age of Structure	-700.17	-0.0017	-0.062
	(-5.18)*	(-7.31)*	(-7.92)*
Number of Bedrooms	-12,295	-0.012	-0.045
	(-4.41)*	(-2.52)*	(-1.09)
Number of Bathrooms	-979.49	-0.0036	0.031
	(-0.33)	(-0.69)	(1.08)
Distance to Light Rail Station	9,200	-0.018	0.031
	(2.31)*	(2.49)*	(3.44)*
Distance to Downtown Hillsboro	-15,806	-0.016	-0.052
	(-2.63)*	(-1.47)	(-2.29)*
Distance to Highway 26	-23,958	-0.038	-0.24
	(-4.30)*	(-3.79)*	(-5.09)*
Location Adjacent to Busy Street	-6,493	-0.024	-0.021
	(-4.41)*	(-2.11)*	(-2.94)*
Noise Level	263.05	0.000013	0.043
	(0.35)	(0.11)	(0.24)
Distance to Runway	17,323	0.022	-0.062
	(2.19)*	(1.53)	(2.56)*

*90% significance level, two-tailed test. Sample size is 495. Dependent variable is sale price in one of the above functional forms.

MODEL 2

Coefficient	Linear	Semi-Log	Double-Log
Constant	154,538	5.33	2.86
	(3.19)*	(20.13)*	(8.99)*
Area of Lot	1.77	0.000003	0.189
	(6.87)*	(7.50)*	(10.96)*
Structure Size	83.77	0.00016	0.556
	(20.91)*	(22.44)*	(16.38)*
Age of Structure	-698.10	0.0017	-0.0595
	(-5.16)*	(-7.18)*	(-7.73)*
Number of Bedrooms	-12,295	-0.0126	-0.0506
	(-4.41)*	(-2.518)*	(-1.24)
Number of Bathrooms	-911.9	-0.0299	0.0177
	(-0.31)	(-0.57)	(0.63)
Distance to Light Rail Station	9,178	0.0171	0.0274
	(2.30)*	(2.39)*	(3.13)*
Distance to Downtown Hillsboro	-15,783	-0.0161	-0.0607
	(-2.62)*	(-1.49)	(-2.69)*
Distance to Highway 26	-23,962	-0.0384	-0.274
	(-5.16)*	(-3.85)*	(-5.84)*
Location Adjacent to Busy Street	-6,536	-0.0246	-0.058
	(-0.94)	(-1.96)*	(-4.55)*
Noise Level	-147.95	-0.0038	-0.022
	(-0.19)	(-0.805)	(-0.123)
Interaction Term	319.4	0.00301	0.0749
	(2.18)*	(0.843)	(3.11)*

*90% significance level, two-tailed test. Sample size is 495. Dependent variable is sale price in one of the above functional forms.

MODEL 3

Coefficient	Linear	Semi-Log	Double-Log
Constant	115,981	5.11	2.82
	(2.65)*	(65.43)*	(8.69)*
Area of Lot	1.79	0.0000035	0.183
	(6.91)*	(7.61)*	(10.69)*
Structure Size	85.73	0.00016	0.57
	(21.94)*	(23.64)*	(16.88)*
Age of Structure	-687.62	-0.0017	-0.065
	(-5.04)*	(-7.07)*	(-8.28)*
Number of Bedrooms	-12,218	-0.012	-0.051
	(-4.37)*	(-2.49)*	(-1.19)
Number of Bathrooms	-1,318	-0.0041	0.027
	(-0.45)	(-0.78)	(0.94)
Distance to Light Rail Station	15,151	0.026	0.038
	(4.93)*	(4.65)*	(4.43)*
Distance to Downtown Hillsboro	-3,107	0.00037	-0.0067
	(-1.61)	(1.08)	(-0.48)
Distance to Highway 26	-13,592	-0.025	-0.155
	(-4.31)*	(-4.36)*	(-4.61)*
Location Adjacent to Busy Street	-5,934	-0.023	-0.025
	(-0.85)	(-1.84)*	(-1.72)*
Noise Level	-25.08	-0.00055	0.0087
	(-0.33)	(-0.40)	(0.47)
Distance to 55 DNL Contour	-16,498	-0.043	-0.0115
	(-1.51)	(-2.24)*	(-1.77)*

*90% significance level, two-tailed test. Sample size is 495. Dependent variable is sale price in one of the above functional forms.

MODEL 4

Coefficient	Linear	Semi-Log	Double-Log
Constant	112,147	5.11	2.88
	(2.58)*	(65.77)*	(8.89)*
Area of Lot	1.79	0.0000035	0.187
	(6.90)*	(7.61)*	(10.59)*
Structure Size	85.74	0.00016	0.549
	(21.94)*	(23.64)*	(15.85)*
Age of Structure	-688.1	-0.0017	-0.0621
	(-5.05)*	(-7.08)*	(-7.92)*
Number of Bedrooms	-12,222	-0.0124	-0.0456
	(-4.37)*	(-2.49)*	(-1.09)
Number of Bathrooms	-1,314	-0.0041	0.0373
	(-0.45)	(-0.78)	(1.08)
Distance to Light Rail Station	15,127	0.0255	0.0307
	(4.92)*	(4.63)*	(3.45)*
Distance to Downtown Hillsboro	-3,111	0.00036	-0.0525
	(-1.71)*	(0.11)	(-2.29)*
Distance to Highway 26	-13,592	-0.0246	-0.241
	(-4.30)*	(-4.35)*	(-5.09)*
Location Adjacent to Busy Street	-5,935	-0.029	-0.031
	(-0.85)	(-1.84)*	(-1.01)
Noise Level	44.94	-0.00039	-0.0192
	(0.59)	(-0.27)	(0.81)
Interaction Term	-299.5	-0.00079	0.0628
	(-1.48)	(-2.21)*	(2.57)*

*90% significance level, two-tailed test. Sample size is 495. Dependent variable is sale price in one of the above functional forms.