

THE IMPACT OF A GENERAL AVIATION AIRPORT
ON SURROUNDING LAND USE PATTERNS:
RICHARD LLOYD JONES JR. AIRPORT

By

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May 2008

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NOMENCLATURE

AC	FAA advisory circular
AGL	above ground level (normally expressed in feet)
ARTCC	air route traffic control center
CBD	central business district (i.e. downtown)
ESRI	Environmental Systems Research Institute, Inc.
FAA	Federal Aviation Administration
FAR	federal aviation regulation
GA	general aviation
GIS	geographic information system
IFR	instrument flight rules
ILS	instrument landing system
MSL	above mean sea level (normally expressed in feet)
RVS	The FAA's three-letter airport identification code for Richard Lloyd Jones Jr. Airport. The original name of the airport was Riverside Airport.
USGS	United States Geological Survey
VFR	visual flight rules

CHAPTER 1

INTRODUCTION

Background

Airports are the most obvious landscape features associated with aviation. Large tracts of land are set aside for the purpose of creating or expanding airports at significant economic and environmental costs. A single airport can leave a sizeable footprint on the landscape. For example, the sprawling Denver International Airport contains 34,000 acres within its boundaries, the equivalent of 53 square miles (DIA 2006). Even a small general aviation airport occupies 15 acres or more, roughly the equivalent of 14 football fields. In addition to size, the noise, pollution, safety concerns, and economic activities generated by airport operations can contribute to distributions of nearby land uses. Perceptions of a property's suitability for specific activities and its value on the real estate market may be attributable either to its proximity to an airport or its location relative to aircraft approach and departure paths. All these factors promote changes to the landscape beyond airport boundaries.

The Problem

In addition to occupying large amounts of land, airports serve as vital components of the national transportation system. As such, they are focal points for the rapid transport of

people and cargo, and they contribute to both our economy and culture. Airports provide a unique service for society. Accordingly, they facilitate specialized activities, have unusual space and operational requirements, and exhibit distinctive characteristics. As a consequence, airports often extend their operational impact beyond their boundaries, thereby influencing surrounding land use patterns. It stands to reason that airports leave recognizable marks on their communities.

Despite the influence of airports, relatively little is known about specific types of impacts that airports have on landscapes. General aviation airports in particular have received sparse attention from planners and academicians when compared to commercial service airports. A review of literature reveals that comparatively limited information is available on the ways general aviation (GA) airports contribute to landscape change beyond their own boundaries. With the continuing growth of cities and suburban communities, it is imperative that planners, developers, and airport managers improve their understanding of the ways in which surrounding properties are affected by airports. Towards that end, this study focuses on spatial characteristics of land use around a large general aviation airport.

Significance of the Study

Understanding the impact of general aviation airports on surrounding land use is important considering the fact that 86 percent of airport construction projects proposed under the National Plan of Integrated Airport Systems (NPIAS) is intended for use by GA aircraft rather than by the airlines (NPIAS 2004). The NPIAS is the Federal Aviation Administration's (FAA) five-year projection of nationwide airport improvements. It

identifies U.S. airports considered significant to the national air transportation system. Airports included in the NPIAS are eligible to receive grants under the FAA's Airport Improvement Program (AIP). Of the \$39.5 billion total planned for infrastructure development funds over a five-year period, \$9.6 billion (24 percent) is intended for reliever airports¹ and other general aviation airports (NPIAS 2004). In addition, construction on other general aviation airports falling outside the scope of the NPIAS may also be proposed and existing airports may be expanded. At the same time, some airports are closing and being redeveloped for non-aviation purposes. Such landscape changes involving major cultural features have significant implications.

General Aviation

Since this study addresses general aviation, an explanation of the term is provided here for the benefit of the reader. Civil aviation falls into one of two categories: air transport (or commercial aviation) and general aviation (NPIAS 2004). General aviation consists of private and business aviation, including small aircraft rentals and flight instruction. It is distinguished from airline, air cargo, and charter operations that use large, transport-type aircraft (those exceeding 12,500 pounds maximum takeoff weight). General aviation is considerably more diverse than transport aviation in terms of both the types of aircraft and the kinds of operations.

The vast majority of airports in the United States, as well as the largest number of registered aircraft, are associated with general aviation. While airlines are restricted to operating out of only a few hundred airports, general aviation aircraft operate at nearly

¹ A reliever airport is a general aviation airport designated by the FAA to serve as a high capacity GA airport in a metropolitan area for the purpose of relieving pressure on busy commercial service airports (NPIAS 2004).

every civil airport in the United States. The FAA recognizes 19,983 landing facilities in the United States. Only 383 of those—less than two percent of all the nation’s airports—have commercial service exceeding 10,000 passenger enplanements a year (FAA 2007a; NPIAS 2004). Looking at it another way, over 98 percent of America’s airfields are not major commercial airports, but are used primarily by general aviation aircraft (Appendix A). For this reason, general aviation airports are an important resource for private transportation.

Not only are most American airports used exclusively by general aviation, but GA represents the bulk of U.S. civil aviation operations. The FAA estimates that during 2005 over 224,000 GA aircraft were active in American skies, compared with about 19,000 air carrier aircraft (FAA 2007a; Appendix B). Although general aviation’s share of overall U.S. air traffic is forecasted to shrink slightly relative to the volume of commercial aviation, Table I suggests that it will nevertheless continue to be the busiest segment of civil aviation through 2015. In that year general aviation is expected to comprise 56 percent of all non-military flying.

	Aircraft Operations				
Aviation Sector	2003		2015 (forecast)		Annual Growth
	millions	%	millions	%	
Total	62.7	100%	80.5	100%	2.4%
General Aviation	35.5	56.6	43.4	53.9%	1.9%
Air Carriers	24.2	38.6	33.9	42.1%	3.3%
Military	3.0	4.8	3.1	3.9%	0.3%

Source: NPIAS 2004

Table I. Forecast growth in U.S. aircraft operations.

General aviation keeps airports busy. In 2006, GA flying activity (including on-demand air taxis) accounted for two-thirds of airport operations and two-thirds of

instrument operations at airports with FAA control towers (Table II). This takes on greater significance if one considers that much of the general aviation fleet operates at non-towered airports and so is not included in this tally. Six of the 50 busiest American airports in 2005 were general aviation airports (Table III). In describing the level of activity at an airport, a common statistic is the number of aircraft operations at an airport within a 12-month period, with each takeoff or landing counting as one operation. The more operations an airport has, the more that nearby property is exposed to aircraft maneuvering at low altitude, with associated impacts on persons beneath flight paths.

FAA-Controlled Air Traffic					
Type of Activity	General Aviation		Air Carriers	Military	TOTAL
Airport Operations Logged by FAA Control Towers	29,940	66.9%	13,132	1,679	44,751
Instrument Operations Logged by FAA Control Towers	29,045	63.4%	14,108	2,642	45,795
Aircraft Handled by FAA ARTCC's	17,692	38.2%	24,486	4,122	46,300

Source: Administrator's Fact Book (FAA, April 2007)

Table II. Comparison of FAA-controlled air traffic among general aviation, air carriers, and military (2006).

Rank	Airport	Location Identifier	City	State	Area (Acres)	Based Aircraft
1st	Van Nuys	VNY	Van Nuys	California	725	776
2nd	Deer Valley	DVT	Phoenix	Arizona	914	1,149
3rd	Centennial	APA	Englewood	Colorado	1,400	710
4th	R.L. Jones, Jr.	RVS	Tulsa	Oklahoma	664	543
5th	Falcon Field	FFZ	Mesa	Arizona	564	988
6th	Montgomery Field	MYF	San Diego	California	456	555
Average =					787	787

Sources: Administrator's Fact Book (FAA, April 2007); GCR and Associates, Inc. (May 2007)

Table III. The six busiest GA airports in the U.S. (2005).

During the en route phase of flight, air route traffic control centers (ARTCC's) handle more air carrier traffic than general aviation. However, the actual number of GA aircraft in flight is undercounted in this statistic. ARTCC's are primarily intended to track aircraft operating under instrument flight rules (IFR).² While air carriers always operate according to IFR under ARTCC control during the en route phase of flight, many if not most of general aviation aircraft operate under visual flight rules (VFR)³ or in local operations without ARTCC direction. Thus, there are more GA aircraft active and utilizing airports than are reflected in this statistic.

Compared to GA airports, commercial airports and military air bases typically have a larger footprint on the landscape due to the greater operational demands of large transport or high performance airplanes. Although GA airports occupy smaller tracts of land, these are still significantly large areas. For example, the six busiest GA airports occupy land areas averaging 787 acres, or about 1.2 square miles (Table III). As large as that is, however, it is only about 44 percent the size of their commercial airport counterparts having similar rankings, with an average size of 1,795 acres (2.8 square miles).

² Instrument flight rules (IFR) are a set of rules and procedures established by the FAA governing flight in meteorological conditions unsuitable for flight by visual references. However, IFR may also be followed when conducting flight in visual conditions.

³ Visual flight rules (VFR) are a set of rules and procedures established by the FAA governing flight in meteorological conditions suitable for flight by visual references.

CHAPTER 2

REVIEW OF LITERATURE

Overview

This chapter reviews literature dealing with airports and land use. It begins with a general discussion of literature both within and outside the field of geography that deals with relationships between airports and adjacent land use. Next, the chapter highlights studies and government policies pertaining to the effects of noise, safety concerns, environmental degradation, and economic issues on land uses adjacent to airports. Another section examines literature going beyond airports by addressing land use issues related to large construction projects such as transportation facilities, sports complexes, convention centers, and educational institutions. Finally, land-use models used to explain spatial patterns are reviewed for their potential to reveal a better understanding of land-use patterns associated with airports.

Airports and Land Use

Research by Geographers

Academic articles and books that address aviation from a geographic perspective are few and limited to transport aviation. For example, a comprehensive book called *Modern Transport Geography* touches on major forms of transportation, but omits reference to

the role of, or issues pertaining to, general aviation (Hoyle and Knowles 1998). Although some dissertations and theses mention general aviation, only a small number of studies examine spatial patterns of land use around general aviation airports or explore the influence of airport activities over surrounding landscapes.

Cidell (2003a) briefly notes general aviation airports in discussing the conversion of former military bases to new uses. McLemore (1988) examined airports having industrial parks located on or adjacent to airport property. He found that airport operators may seek to be affiliated with industrial parks, since the presence of an industrial park associated with the airport can protect the airport from encroachment by less compatible land uses and can boost economic activity nearby. However, McLemore does not consider an airport-associated industrial park to be a well-defined land use and its relationship with the associated airport is still not well understood.

Cidell (2003b) examined the interplay of global air transport demand and local land use issues with regard to proposed expansion projects at three major commercial airports. In his dissertation, McAdams (1995) evaluated evolving urban structure, examining the role of Milwaukee's General Mitchell International Airport as an emerging urban node and how it has impacted surrounding land use. However, this study did not use especially detailed information pertaining to patterns of land use around airports nor does it include a discussion of land use around general aviation airports. Adedibu (1977) examined changes in commercial land use adjacent to Jacksonville International Airport in Florida, noting the role that airports play as initiators of land-use changes. He notes that nearly any airport exerts "some influences in changing the adjacent land uses" (p. 41) and observes that as an airport increases in size, its impact on surrounding land uses become

more noticeable (Adedibu 1977).

Griffith is one of only a few geographers who have published research pertaining specifically to general aviation, but his work does not examine land use patterns (1955). Although Carlsen (2002) discussed land use in his study focused on Denver International Airport, his research did not involve a detailed analysis of land use patterns. Nonetheless, among his research findings was the observation that airport operations discourage the development of housing nearby (Carlsen 2002).

At least two works address the interplay between surface features and aviation. Carson (1990) highlighted the impact of surface features on controlled airspace and how they effect general aviation. Local terrain, the relative location of nearby airports, and the spatial configuration of airports were found to have influenced navigation and air traffic control, necessitating modifications to controlled airspace. In discussing the geography of air transportation, Sealy (1968) offers several considerations guiding airport siting and configuration. These include the importance of having adequate room for future expansion and how the presence of an airport affects areas beyond its boundaries. Among factors examined were noise and safety restrictions, as well as the best use of the surrounding land. While his book focuses on international air transport, Sealy acknowledged the importance of smaller airports, suggesting they should be studied more extensively.

Research outside Geography

Research outside the field of geography also addresses land use issues as they impact airports. In the course of Bright's (1980) examination of the airport planning process, she

made references to the secondary impacts of airport development and expansion, and discussed land-use compatibility issues. Bednarek and Bednarek (2003) trace the historical development of general aviation, but do not delve much into land-use issues. A related book by Bednarek (2001) chronicles the early development of airports up to 1947, but again, does little to address their impacts on adjacent properties. The economic impact of general aviation airports is addressed in at least two academic articles (Weisbrod 1991; Babcock 2000). However, neither addresses spatial patterns associated with airport development or expansion.

Impacts on Land Uses Adjacent to Airports

Four factors contribute to an airport's influence on nearby land use: noise, safety concerns, environmental degradation, and economics. The first three are considered undesirable impacts, or disamenities. An airport land use compatibility guide prepared by an aviation consulting firm refers to the undesirable influences of the first three as it discusses the discomfort felt by residents and commercial interests with regard to noise, pollution, safety concerns, and the general annoyance of aircraft flying low overhead (William V. Cheek and Associates 2000). On the other hand, the economic factor can go either way. Airports can have a beneficial effect by creating jobs and attracting certain economic activities, but the presence of an airport can also be detrimental to some kinds of economic activities.

Noise

The single most significant nuisance impact from airports is noise generated by

aircraft, especially from large jets. Federal Aviation Regulation (FAR) Part 150, entitled “Airport Noise Compatibility Planning,” addresses airport noise compatibility planning at public-use airports. It provides recommended guidelines concerning compatible and non-compatible land uses from the perspective of noise exposure levels (14 CFR Part 150, 2006). A compatible land use under FAR 150 is considered to be any land use that is not negatively impacted by “excessive” noise levels generated from airport activities. What constitutes an excessive level of noise varies according to the type of land use involved. Also, local communities have discretion to set their own noise tolerance limits for various land uses in accordance with local preferences.

The technique used by the FAA for mapping noise contours and for defining compatible land uses is called the *yearly day-night average sound level* (L_{dn}), which is measured in decibels (dB). The 65 dB L_{dn} contour is established by FAR 150 as a threshold for noise tolerance. Below this level, all land uses are deemed appropriate, but above this level, certain land uses are considered incompatible due to excessive noise. With rising noise levels above 65 dB, compatible land-use types become fewer, restricting land-use options. For example, areas exposed to more than 65 dB L_{dn} are considered incompatible for residential areas, transient lodgings, schools, and outdoor amphitheaters according to the FAA (14 CFR Part 150, 2006).

The deleterious effects of unwanted noise can initiate changes in land use patterns surrounding the source of the nuisance. For example, residential real estate prices in the vicinity of airports tend to be depressed, especially near commercial and military airports with frequent jet traffic. Nelson (1980), Sutton (1999), Espey and Lopez (2000), and Bell (2001) have described and quantified the diminution of residential property values on the

real estate market where properties are located near a major airport.

Bell (2001) explains how homes suffer a reduction in value when located beneath busy approach and departure paths of jet airliners operating at major commercial airports, or when beneath other low-altitude flight corridors frequented by noisy transport aircraft. Likewise, some property values drop after an airport is constructed nearby (Bell 2001). Accordingly, with increasing distance away from airport operations areas and flight paths, property values tend to rise and stabilize as they become less affected by noise, pollution, safety concerns, and visual intrusion. This is especially evident for residential real estate.

The trend toward declining property values for residential real estate with increasing nearness to a major transportation facility, such as an airport or highway, is supported by a survey. Twenty-two sites revealed a drop in real estate values of 0.4 to 1.1 percent for each one-decibel increase in the noise level (Nelson 1980). A similar trend was found by Espey and Lopez (2000) in their examination of real estate values around Nevada's Reno-Tahoe International Airport. Their results further corroborate the association between increasing noise levels and declining property values. The combination of airport noise and the perceived disamenity of living so close to the airport resulted in property values one mile from the airport averaging 2.6 percent less than equivalent houses two miles from the airport (Espey and Lopez 2000).

While the preceding studies are limited to prices associated with detached homes, a similar study of Vancouver International Airport included multiple-unit residential condominiums and vacant land (Uyeno, Hamilton, and Biggs 1993). This study found that the negative impact of airport noise depreciated house values by 0.65 percent for

each one-decibel increase in the sound level, while condominiums depreciated even more at 0.90 percent (compare to Nelson 1980). The depression on prices for vacant land was even greater than either of these.

Not only are real estate values negatively affected by exposure to aircraft noise, but noise has also been shown to discourage residential, school, and similar noise-sensitive uses on nearby properties. Espey and Lopez (2000) found an association between sound levels and the number of dwellings. Where sound levels in the airport vicinity were higher, fewer houses were present. The nuisance of aircraft noise may result in the construction of fewer residential structures, changes in the type of existing residential usage, or the replacement of residential uses with more compatible uses. The effect can be accentuated through government zoning ordinances and the purchase of adjacent properties.

Tulsa International Airport is an example of how a large airport can alter residential patterns and property values. The Tulsa Airports Improvement Trust was considering proposals for mitigating the effects of aircraft noise near the airport for residences located within noise contours exceeding the FAA's recommended noise standard for residential use. As stated previously, this standard is a yearly day-night average sound level of 65 decibels (L_{dn} 65 dB). One proposal was to acquire 550 homes in two neighborhoods southeast of the airport, while others involved paying property owners for avigation (flyover) easements,⁴ installing sound insulation in residences, providing assistance to property owners for selling their properties, and acquiring affected properties from their owners (Stewart 2007). Some 1,698 homes near the airport were located within noise

⁴ An avigation easement is the right to unlimited flight in the airspace above a property, normally purchased from the property owner by the airport operator.

contours exceeding 65 decibels, making them eligible for some form of noise mitigation (Steward 2007). Since 2000, the owners of 933 homes have already participated in noise mitigation efforts, with 809 agreeing to have sound insulation installed and 68 selling flyover rights. Five homeowners have even agreed to vacate their properties and sell them to the Trust, while 51 owners have accepted assistance for putting their property up for sale (Steward 2007). Issues associated with the remaining 765 properties have not yet been resolved.

Safety Concerns

The presence of an airport also influences nearby land use in response to the need for ensuring safety, both for passengers and for bystanders on the ground. In an effort to ensure clear approaches and departure paths as well as to minimize the existence of hazardous obstructions in the airport vicinity, the FAA published FAR Part 77, “Objects Affecting Navigable Airspace” (14 CFR Part 77, 2006). FAA standards seek to eliminate natural growth, terrain, man-made structures, and materials or equipment that may pose an obstruction to safe air navigation, whether located on or within the vicinity of an airport. Thus, efforts taken to ensure unobstructed aerial navigation have consequences for the landscape well beyond airport boundaries.

Another safety consideration is the threat posed by an aircraft colliding with animals. In-flight collision of an aircraft with birds, bats, or insect swarms is most likely in the airport vicinity due to aircraft flying at low altitudes during approach and departure phases. During ground operations, the chief collision concern is with large mammals straying onto runways and taxiways. In an effort to reduce the likelihood of striking birds

or other animals, the FAA recommends specific separation distances between an airport's air operation area and wildlife attractants (FAA 2004). Federal law also limits the construction of new municipal solid waste landfills (MSWLF) in the vicinity of some public airports to no closer than six miles in order to minimize the potential for bird strikes (FAA 2000).

Another aspect of safety is the public's perception of threats as a result of being in the proximity of aircraft operations. Popular anxiety prompts public policies restricting land uses near airports, especially in proximity to the approach and departure ends of a runway. Apart from government intervention, safety concerns may also limit the market appeal of neighboring properties to low-density uses.

Concerns over safety are not unfounded. In addition to inbound and outbound air traffic, training and practice activity within the airport traffic pattern increase the chance of accidents. Not surprisingly, most aircraft accidents occur on or in the vicinity of airports. Also, most aircraft accidents involve general aviation. This may be attributable to several factors, including differences in flight experience, training, proficiency, operational profiles, and support systems, as well as aircraft condition and capabilities.

On August 17, 2004, a fatal accident occurred in the city of Jenks, Oklahoma, just half a mile southwest of Richard Lloyd Jones Jr. Airport, killing all three people aboard a Cessna 210 (Figure 1). Shortly after takeoff, the engine lost oil pressure and the pilot was attempting to return to the airport when the single-engine plane crashed into a field dangerously close to a housing addition. Although the crash site was within 50 feet of a home, no structures were damaged nor was anyone on the ground injured (Elliott 2004). While residents were fortunate to have been left unscathed, similar incidents could have

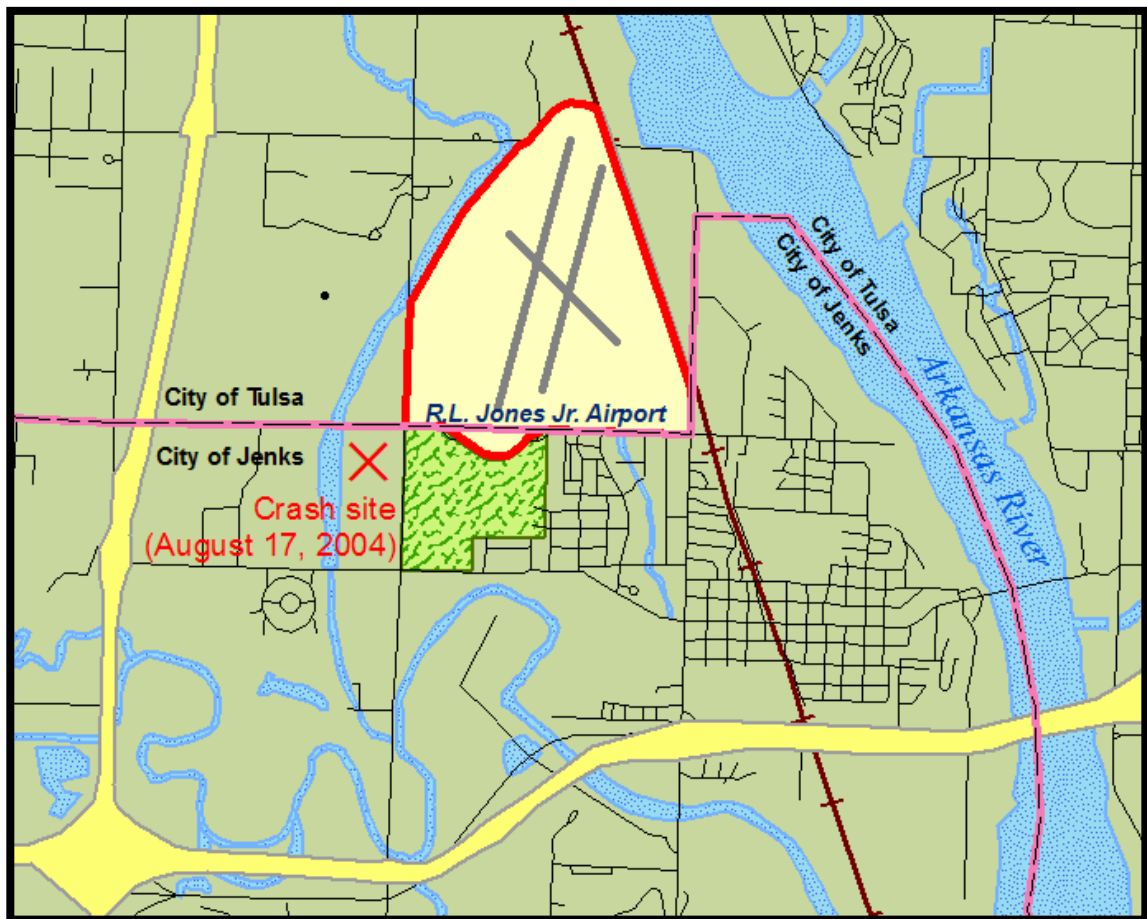


Figure 1. Fatal crash of departing airplane one-half mile southwest of the airport.

disastrous consequences for persons living near the airport. After the accident, one of the nearby residents expressed feelings common to many who live near an airport when she admitted fearing for her family's safety after they moved so close to the airport (Elliott 2004).

Environmental Impacts

Airports have environmental repercussions extending beyond their boundaries. Airport construction or expansion disturbs the existing landscape, creates unwelcome noise, and is associated with air pollution, toxic runoff, and disturbance to wildlife (Horonjeff and McKelvey 1994). Other environmental factors to consider are airport influences on vegetative cover, soil composition, erosion, topography, water runoff, and infiltration (Horonjeff and McKelvey 1994). A more subjective impact is that of aesthetics. Many people do not want to look at airports from their homes.

Although aviation has a small environmental impact relative to other modes of transportation such as highways, demand for air travel may necessitate increases in the amount of land area devoted to aviation. At the same time, air transportation may face future constraints stemming from concerns over its environmental impacts. Plans to increase airport capacity by lengthening runways or adding an additional runway are sometimes delayed, or cancelled altogether, in response to questions over the impact on local air and water quality, wildlife, and noise encroachment on nearby communities (Cidell 2003b). Besides being noisier than most other transportation modes, aircraft emit noxious fumes and irritating particulate matter. Spilled fuel and oil, and the presence of de-icing fluid on airport property are other concerns.

Pollutants are not the only environmental issue. The wide open spaces of airports attract wildlife that can pose a collision hazard to aircraft and ground vehicles. As noted previously, some types of agriculture are discouraged near the airport in order to reduce concentrations of birds, large mammals, and other wildlife in airport vicinities (FAA 2004). In addition, landfills that attract scavengers cause problems near airports (FAA 2000). On the other hand, airport construction projects can be detrimental to some types of animals, especially endangered species. In some cases this may lead to changes in the airport boundary or the establishment of wildlife sanctuaries near an airport.

Economic Influences

Airports also have economic influences on surrounding areas, which in turn influence land use. Unlike the previous three factors, the economic influence may often be viewed favorably. An airport may attract certain types of industries and businesses. According to Babcock (2000), the economic impacts of an airport can be attributable to the airport itself, as well as to various businesses on airport property that provide aviation-related services or supplies, such as fuel. In addition, airport users in the local area spend money on food, rentals, lodging, or related services.

Commercial airports are not the only types of airport facilities to affect communities economically. General aviation airports are integral parts of local economies. Many businesses transport their employees and company materials using general aviation airports. In fact, nearly 70 percent of the hours flown by general aviation involve transportation for business purposes (AOPA 2007b). In a survey of Massachusetts businesses using GA aircraft, 26 percent said they would relocate or go out of business if

there was not a general aviation airport available. Another 23 percent said that access to an airport was an essential factor in their original site selection (Weisbrod 1991).

Land Use Not Involving Airports

Transportation Facilities

A look at research examining land uses adjacent to large construction projects provides additional insights. For example, Sutton (1999) examined changes to residential, commercial, and office uses in Denver following the construction of the I-225 beltway in a relatively undeveloped area. He found that residential and commercial land uses were gradually reoriented along the route in response to its construction (Sutton 1999). As with airport studies, the noise and air pollution associated with interstate highways tended to suppress nearby residential property values, though no specific distances were given for properties affected (Sutton 1999). In another highway study, Sanchez (2004) examined the relationship between several urban highway projects in Oregon intended to increase traffic capacity and their associated land-use changes. Although his findings show that land use is significantly changed along highway corridors, his study does not reveal specific information related to distances from the corridor (Sanchez 2004).

Polzin (1999) found that land use responded to transportation investments in several ways. Investments provided greater accessibility to targeted areas, helped spur economic development in those areas, assisted in curbing urban sprawl, and contributed to a sense of progress that encouraged land use change. However, other factors such as the mode of transit, the routes selected, and public demand for transportation were also found to be important factors (Polzin 1999).

Access to transportation facilities is normally an important issue influencing the location of an enterprise. Ryan (2005) analyzed the significance of access to highways compared with access to light rail systems in influencing the locational decisions for both office and industrial properties in San Diego. She found that office properties are drawn to highway access, but not light rail access. For some office properties, Ryan also found evidence that proximity to similar land uses was valued more highly than access to the central business district (Ryan 2005). Similarly, it appeared that for industrial firms, easy transportation access was less significant as a locational factor compared with the desire to locate near similar land uses. This clustering of similar economic activities is sometimes called agglomeration (Ryan 2005). Companies often realize an economic advantage in terms of cost savings or access to customers from agglomeration (Ryan 2005).

At least two other studies examined the impact of trams (light rail) on land use. Haywood (1999) revealed extensive land use change associated with a tram route in the United Kingdom. Citing the effect of distance decay, he notes that the effect of the tram route on nearby land uses weakens with increasing distance. Miras-Araujo (2005) examined how the growing branches of a tram line in a Spanish city influenced the spatial structure of the city's economy over time (Miras-Araujo 2005). His study shows that the siting and layout of transportation facilities can influence the location of economic activities, spatial variation in land rents, and intra-urban movement (Miras-Araujo 2005). It also suggests that the degree to which transport facilities affect land use can change over time due to technological improvements, competition from other transport modes, or the evolution of the city structure itself (Miras-Araujo 2005).

Major Construction Projects

Several other studies cited herein deal with land-use planning concepts or large land-use projects not involving transportation. Engelen (2005) lays down principles underlying good planning practices for developing mixed land uses that are multi-functional and complementary. While not addressing the land-use impact of a specific type of project, he draws attention to the important role of planning and decisions in determining urban landscapes. One of the ingredients for success is taking into consideration the transportation needs of the development (Engelen 2005). Also, with limited land available for construction and the high cost of development, communities and developers need to cooperate with each other. To accommodate multiple land uses, appropriate zoning ordinances must be enacted, and local and state laws may need to be re-written.

Hequet (2006) discusses the recent planning trend in utilizing large sports facilities, such as arenas and stadiums, as mixed-use anchors intended to complement other developments nearby. New arenas and stadiums are becoming the focal points of urban sports districts and are attracting other substantial developments. Public construction projects such as convention centers and performing arts centers, various commercial projects, and even residential developments are appearing near these sports facilities.

Construction can result in a considerable transformation of the urban landscape, including the razing of old warehouses and other dilapidated structures, the loss of historical sites, changes to or elimination of neighborhoods, and new or modified streets. The acreage surrounding major sports facilities is normally included in a coordinated development plan that involves large parcels of land. For example, in conjunction with the opening of an arena in Columbus, Ohio, the developer also prepared the surrounding

95 acres to provide land for restaurants, entertainment facilities, office space, and 500 housing units (Hequet 2006). Similarly, in conjunction with the 2006 opening of the new Busch Stadium in St. Louis, the former baseball stadium was demolished. In its place, portions of the land are being redeveloped into a 12-acre mixed-use development featuring tourist attractions, shops facing a one-acre plaza, office space, and 400 residential units (Hequet 2006). The opening of San Diego's Petco Park baseball stadium in 2004 triggered about 26 blocks of re-development in a rundown section of the city, with the construction of hotels, creation of shopping centers, and development of residential areas (Hequet 2006).

Other studies address the role of major sports facilities as catalysts for urban redevelopment (Chapin 2004). Cities commonly construct large sports, entertainment, or convention facilities to stimulate downtown revitalization in failing districts (Chapin 2004). Three indicators of urban redevelopment in response to major construction projects like these are: 1) the re-use of existing buildings or spaces, 2) new construction nearby that is linked to the initial investment, and 3) the emergence of a new, distinctive identity for the district (Chapin 2004).

In addition to sports complexes, other large projects such as convention centers and performing arts centers have a significant impact on nearby land uses. Minton (2006) focused on the impact of new convention centers on fostering nearby economic activity and development. Visitors need a place to park, eat, and spend the night, so it's natural that multi-story parking garages, hotels, restaurants, complementary attractions, and office buildings would be attracted to convention centers. Even some residential development is occurring in response to new convention centers (Minton 2006). Aside

from their economic influence and development impact, convention centers are a significant land use simply because they occupy many acres of land in highly desirable central business districts (CBDs). In many cities, major urban development projects are prompting the need for updating local land-use codes (Minton 2006).

Two examples illustrate the landscape-changing influence of large projects such as convention centers. Houston's convention center, together with the baseball stadium, has contributed to the transformation of the downtown. The area within a mile of the convention center has seen the emergence of sports and retail complexes, a theater district, and hotels (Minton 2006). The convention center's 12-acre lawn has been developed as an urban park featuring a lake, amphitheater, children's play area, dog section, and two restaurants (Minton 2006). The 2004 opening of the convention center in Columbia, South Carolina, has contributed to an on-going upgrade of the city's downtown, replacing the former warehouse and factory district with restaurants, bars, boutiques, galleries, and professional offices (Minton 2006). The redevelopment is a continuation of the trend begun by the opening of a performing arts center and an arena, and by infrastructure improvements, the construction of parking facilities, and new landscaping (Minton 2006).

Educational Institutions

Gumprecht's (2003) observations regarding the impacts of American colleges and universities on their communities are relevant because one can draw comparisons between a college campus and an airport. As he likens college towns to "an academic archipelago" (Gumprecht 2003, 51), airports may be similarly analogized as islands

dotted across the landscape. A college campus or a busy airport can be the focal point of a town and in some ways acts as a self-contained city (Gumprecht 2003). Both facilities require large amounts of contiguous land and both provide distinctive services. Also, both have influences on their communities that extend beyond their property lines and include changes to land uses.

Characteristic residential and commercial landscapes have developed around college campuses, as well as the predominance of certain land uses. Distinctive residential patterns emerge adjacent to a campus in response to social differences among students, faculty, and others in the community (Gumprecht 2003). College campuses also impact economic patterns. The unique demographics of a college town have led to the emergence of specialized commercial districts and student-oriented religious organizations close to campus (Gumprecht 2003). Furthermore, in response to the prevailing values of college communities, such places tend to enact zoning and land use decisions characteristic of a college culture (Gumprecht 2003).

Agricultural Land-Use Model

Johann Heinrich von Thünen's (1783-1850) agricultural location theory and related model is of special interest to economic geographers. Published in 1826, von Thünen was the first to explain spatial patterns of agricultural land use around market centers. Cities, the chief markets for agricultural products, were found to exert an influence on the agricultural patterns of their surrounding areas (Hall 1966). To explain these observations, von Thünen theorized that certain kinds of agricultural activities tend to locate at specific distances from cities. This was used to create a land-use model

explaining these distinctive and predictable patterns (Hartshorn 1992).

Bands or rings of concentric agricultural zones surround a market area, with each ring corresponding to an agricultural product. Von Thünen's theory recognizes that there is a tradeoff between distance and production costs. The closer to the market, the cheaper the transportation costs, but the more expensive the land. Each activity would find its optimal distance from the market. Though his theory is nearly 200 years old and limited to agricultural land uses, it is useful in considering land use patterns around airports.

Urban Spatial Models

Another concept regarding land use is derived from models of urban spatial structure. For example, as cities grow outward from an original settlement area, they develop concentric rings of successive land uses, much like a tree trunk growing year by year. The idea of concentric rings around a focal point is at the heart of the concentric ring model of urban spatial structure (Burgess, Park, and McKenzie 1925). In that model, the city's central business district is the focal point around which concentric rings emerge, distinguished by their chronological development. Each new ring is characterized by distinctive attributes of the timeframe during which it was developed, such as the architectural styles in vogue and the technologies available. This concept may also have application for patterns of land use around airports.

Others have described urban spatial structure as resembling sectors radiating outward from the city center (Hoyt 1939). Predominant land uses become established at different sides of the city and tend to be perpetuated as the city expands outward. A slightly more complex view of urban structure is found in the multiple nuclei model (Harris and

Ullman 1945). Here, each land use is concentrated in certain parts of the city, which function as nodes for that type of use. Drawing from these three models of urban structure, the airport would be analogous to the central business district or the node around which the landscape is organized.

CHAPTER 3

THEORETICAL BACKGROUND

Overview

This chapter provides a theoretical background to the analysis of land use around airports. Two research questions are introduced, along with their respective hypotheses.

Some Considerations

The overarching question posed in this study asks, “In what ways are the areas around a general aviation airport impacted by its operational activity?” As stated in the previous section, theoretical precedents for this type of study exist for both agricultural and urban land use models. With inspiration from von Thünen’s 1826 model of agricultural land use (edited by Hall 1966) and spatial models for describing urban spaces a (Burgess, Park, and McKenzie 1925; Hoyt 1939; Harris and Ullman 1945), this study examines the nature of land use around a general aviation airport, with the airport functioning as the central focus around which land use is arranged.

Research Questions and Hypotheses

In contemplating the possible influence of an airport on surrounding land-use patterns, there are essentially two issues to address. One involves the *range* of the airport’s influence – the distance outward from the airport property line to the point where airport influences become negligible. The other question involves the *direction* of the airport’s influence. For example, are there sectors around an airport in which airport operations

have more influence over land use than others? If so, is this principally due to runway orientation or are there other forces at work? These broad questions are stated formally in the two research questions. Each research question has two hypotheses to be tested.

Research Question 1: In what ways does land use change with increasing distance from a general aviation airport?

It is assumed that land uses more compatible with airport operations will be closer to an airport. Compatible land uses are typically those less sensitive to noise, pollution, or safety concerns, such as agricultural or industrial activities (William V. Cheek and Associates 2000). As noise exposure levels increase above 65 dB L_{dn} , compatible land use options diminish. Those uses deemed less compatible with airport operations, such as residential areas, schools, or hospitals, tend to be found at greater distances from the airport (Bell 2001; Carlsen 2002; Espey and Lopez 2000; Sutton 1999). One would expect that spatial variation in compatibility, and market value among both open lots and developed properties near airports, would have an affect on parcel size, the degree of care expended on a given property, and how that land is used. These spatial variables related to property values and use should ultimately reveal patterns on the landscape. The spatial distribution of residential land use and population density can be used as indicators to measure the relationship between distance from an airport and the proportion of less compatible land uses.

All land uses in the study area were sorted into one of six categories along a continuum based on their sensitivity to noise. This method will be explained in more detail in Chapter 5, but a brief explanation is necessary at this point. Each of the six land-

use categories was designated as a zone. At one end of the continuum, Zone A represents those land uses having the least sensitivity to noise, and at the other end, Zone F represents the most noise sensitive land uses. Zones B through E fall in between these extremes. While each zone (A through F) was sorted ostensibly according to its sensitivity to noise, included is an implied sensitivity to other nuisance factors, such as environmental degradation, exposure to hazards, and visual intrusion. Zone F, then, is intended to represent those land uses that are the most sensitive to all nuisance factors resulting from airport operations. This is worth keeping this in mind, since hypotheses one and three both refer to Zone F.

First hypothesis (H₁): The proportion of residential, school, and other highly noise-sensitive land uses (Zone F) increases with increasing distance from an airport boundary, up to a distance of one-half mile.

The distance of one-half mile (2,640 feet) was used because it was considered a reasonable estimate of the airport's range of influence. With sparse data from previous studies to go on, it was expected that the airport would have an influence on land use at least this far beyond its boundary, if not further.

Second hypothesis (H₂): Population density increases with increasing distance from an airport boundary, up to a distance of one-half mile.

A key concern related to airports and land use is how airport operations influence the location of noise-sensitive land uses, such as neighborhoods. The second hypothesis uses population density as an indicator of residential land use. An assumption is that population density is closely correlated with residential land use, recognizing that

population densities can vary considerably among areas zoned residential. Nonetheless, areas zoned residential normally should have a higher population density than those zoned for agricultural, commercial, or other activities.

Research Question 2: To what extent does runway orientation influence surrounding land use?

In this study the spatial distribution of residential land use and population density are used as indicators of the influence of runway orientation on surrounding land use. At airports with multiple runways, one runway is often utilized more intensively than others because of prevailing wind direction and speed, the availability of an instrument approach, airport policy, or some perceived desirability on the part of the pilot or controller. Those same factors can influence the preferred direction of approaches and departures, even among airports with a single runway. The result is that each end of any runway may be used differently in terms of phase of flight (approach, departure, or flyover), kinds of aircraft (larger turbine or multi-engine aircraft vs. smaller, piston-powered aircraft), or kinds of operations (takeoff, landing, touch-and-goes, instrument approaches, etc.). Another consideration is that runway orientation also affects areas of land that are overflown by aircraft in the traffic pattern. Adding to this are local policies that modify traffic patterns in the vicinity of the airport, such as special approach or departure procedures, noise mitigation procedures, or non-standard traffic pattern altitudes or directions. All these variables are expected to result in some consequences for the landscape beneath aircraft flight paths, especially beyond each end of a runway.

Factors Determining Runway Orientation

Runways are a vital component of an airport and must be considered in determining airport functions. The number of active runways at an airport, where they are located, how they are oriented⁵, and how they are configured⁶ can be critical to safety, efficiency, and environmental impact (FAA 2007b). Several issues influence runway layout, including environmental factors, obstructions to air navigation, topography, prevailing winds, and wildlife hazards.

Environmental Considerations. A great deal of planning, money, and other resources are devoted to the development and maintenance of runways. To ensure that proposed runways will be compatible with the surrounding area, environmental studies must be carried out that consider impacts on nearby residents, existing or proposed land uses, air and water quality, wildlife, and historical or archeological resources (FAA 2007b). Where low-flying aircraft are passing over environmentally sensitive areas, or creating a significant hazard or nuisance to people, a new runway may be required to divert air traffic in a preferred direction (FAA 2007b).

Obstructions to Aerial Navigation. Prior to constructing a runway, airport planners survey possible obstructions located in airport environs. Runways should be located and oriented so as to provide approaches free of obstructions or other hazards to navigation.

Topography. Although topography (gradient, vegetation, soils, etc.) on the airport

⁵ Runway orientation refers to the direction each runway is aligned with referenced to magnetic north.

⁶ Runway configuration refers to the number and geometric arrangement of runways.

property directly affects runway construction by determining how much grading or drainage work is needed, landforms and tall vegetation surrounding the airport can affect the utility of a runway after construction (FAA 2007b). Steeply rising terrain, significant promontories, or fog-prone areas off either end of a runway are undesirable features possibly necessitating a reorientation of the proposed runway, depending on the seriousness of the impediment.

Wildlife. Another factor in determining runway orientation is the presence of wildlife hazards. Birds in flight pose a collision hazard for aircraft in the air and large mammals on airport surfaces are a hazard during the takeoff run and after touchdown. Planners must take into consideration the relative location of areas that may attract large numbers of birds or other wildlife. Such areas would include sanitary landfills, wildlife management areas, and bird sanctuaries (FAA 2007b).

Affects of Runway Orientation

Airport noise contours are marked in 5-decibel increments and are generally shaped like elliptical bands surrounding each runway, oriented lengthwise along the runway centerline. Their formation around runways indicates a strong connection between runway orientation and the spatial impact of noise. They also suggest the relevance of runway orientation on other negative aspects of airport operations stemming from aircraft operating in a concentrated area along specific flight paths and at low altitudes. Therefore, an important issue in this study is the extent to which runway orientation shapes the distribution of compatible and non-compatible land uses. The expectation is that land uses not compatible with airport operations will be pushed farther away from

the airport when located beneath approach and departure paths. Most of the adverse impact to those on the ground resulting from approaching and departing aircraft is concentrated at the runway ends.

Because of several variables such as prevailing winds and the availability of instrument approaches for each runway, the resulting pattern of impact may be slightly different at each end of each runway. Other factors influencing exposure to overflights in the airport vicinity are the direction, number, length, width, and surface condition of each runway. Also, unique approach or departure procedures established for that airport, strong crosswinds, and pilot techniques must be considered.

On approach to landing, aircraft use lower power settings as they gradually reduce altitude, and are generally closer to the ground beyond the airport compared to departing aircraft. On the other hand, departing aircraft generally apply maximum power for takeoff, at least until a safe altitude is reached. While they are noisier than a landing aircraft, they normally reach a higher altitude by the time they pass beyond the airport property line.

As a good safety practice, pilots taking off continue to fly straight ahead over the runway after becoming airborne and do not begin maneuvering until passing the departure end of the runway and at least several hundred feet above ground level (AGL). Depending on the takeoff performance of the aircraft and the size of the airport, the aircraft may or may not have passed beyond the airport boundary at the time the pilot commences his/her turn. Most airports do not have special departure procedures. Variables such as pilot technique or the presence of a crosswind can influence the ground track from the extended runway centerline. Given all these factors, the effects to those on

the ground of noise and pollution emanating from aircraft, and the safety hazard potential, can vary by runway and from airport to airport.

Third hypothesis (H₃): The proportion of residential, school, and other highly noise-sensitive land (Zone F) underlying the approach and departure paths of the primary runway is at least ten percent less than those same land use types at an equivalent distance in areas which are not underlying such flight paths, as far as one mile beyond either end of the runway.

Unlike the first two hypotheses, which use one-half mile, the second set of hypotheses uses one mile. A greater distance was used regarding the influence of runway orientation because noise-sensitive land uses were expected to be pushed back farther near the runway ends due to greater exposure to nuisance effects. The result would be an elongated spatial pattern centered about the extended runway centerline.

The tendency of commercial airports, interstate highways, and similar nuisance-type facilities to depress residential real estate values and to discourage noise-sensitive uses has been well established (Bell 2001; Espey and Lopez 2000; Sutton 1999). Furthermore, municipal governments commonly enact zoning measures to encourage neighboring land uses to be compatible with one another. In an effort to separate noise-sensitive land uses from those that generate noise, residential neighborhoods, educational institutions, and health care facilities are typically zoned away from an airport, while commercial, industrial, and some agricultural uses are allowed to locate closer. Those residential properties that do underlie aircraft flight paths are more likely to be occupied by low income residents and to be rental properties. People living under noisy aircraft flight paths may be more willing to tolerate the nuisance in exchange for less costly housing. If

they are a renter rather than a property owner, they may also feel less invested in the location and therefore not as likely to complain. In addition, their financial situation limits their housing options and they may not have sufficient means to relocate in another area. On the other hand, airports and other facilities perceived by residents to be nuisances tend to attract industrial or commercial uses, and in some cases, certain recreational uses that are less sensitive to noise or pollution.

Regardless of the facility causing the nuisance, no quantitative data showing a relationship between distance and land use has been completed. The use of ten percent as an indicator for this hypothesis serves as an estimate for the purpose of evaluation. That value was selected for its simplicity and because it was determined to be large enough to detect differences between locations, yet not so large that it would overlook differences that may exist. Likewise, the range of one mile beyond either end of the runway was selected because it was believed that at that distance, most aircraft would have gained sufficient altitude or altered course enough to no longer impact people or property on the ground. Without much guidance from which to draw, ten percent and one mile serve as benchmarks.

Fourth hypothesis (H₄): Population density underlying the approach and departure paths of the primary runway is at least ten percent less than densities at an equivalent distance in areas which are not underlying such flight paths, as far as one mile beyond either end of the runway.⁷

The fourth hypothesis is similar to the second in that both rely on population density

⁷ The reason for using ten percent as the minimum difference and the distance of one mile is the same as for hypothesis three.

as an indicator of land use. Higher population densities within a given portion of the study area correlate with a greater proportion of residential land use in that area.

However, the correlation is not perfect, in that not all areas zoned residential have large numbers of people and some people reside in areas zoned other than residential. Thus, mapping population density is complementary to mapping residential areas. If the hypothesis is retained, it is because fewer people are residing beneath the approach and departure ends of parallel runways.

CHAPTER 4

STUDY AREA

Overview

This chapter discusses the airport selected for this study and its surrounding area. It begins by introducing the airport and providing some historical background.

Subsequently, the chapter discusses the characteristics of the airport, provides selected photographs of areas on and near it, and describes its operational environment. Finally, government's role in influencing land use around the airport is briefly discussed. This includes the federal government's functions in formulating policies and providing funding, state government's role in funding, and the actions of local governments in developing zoning ordinances.

Richard Lloyd Jones Jr. Airport

Description

The area selected for this investigation surrounds Richard Lloyd Jones Jr. Airport in Tulsa, Oklahoma (Figure 2). This airport was selected because it is representative of other large and active general aviation airports. When the airport opened in 1958, Jones was called Riverside Airport in recognition of its proximity to the Arkansas River. Although subsequently renamed to honor Richard Lloyd Jones, Jr., its location identifier,

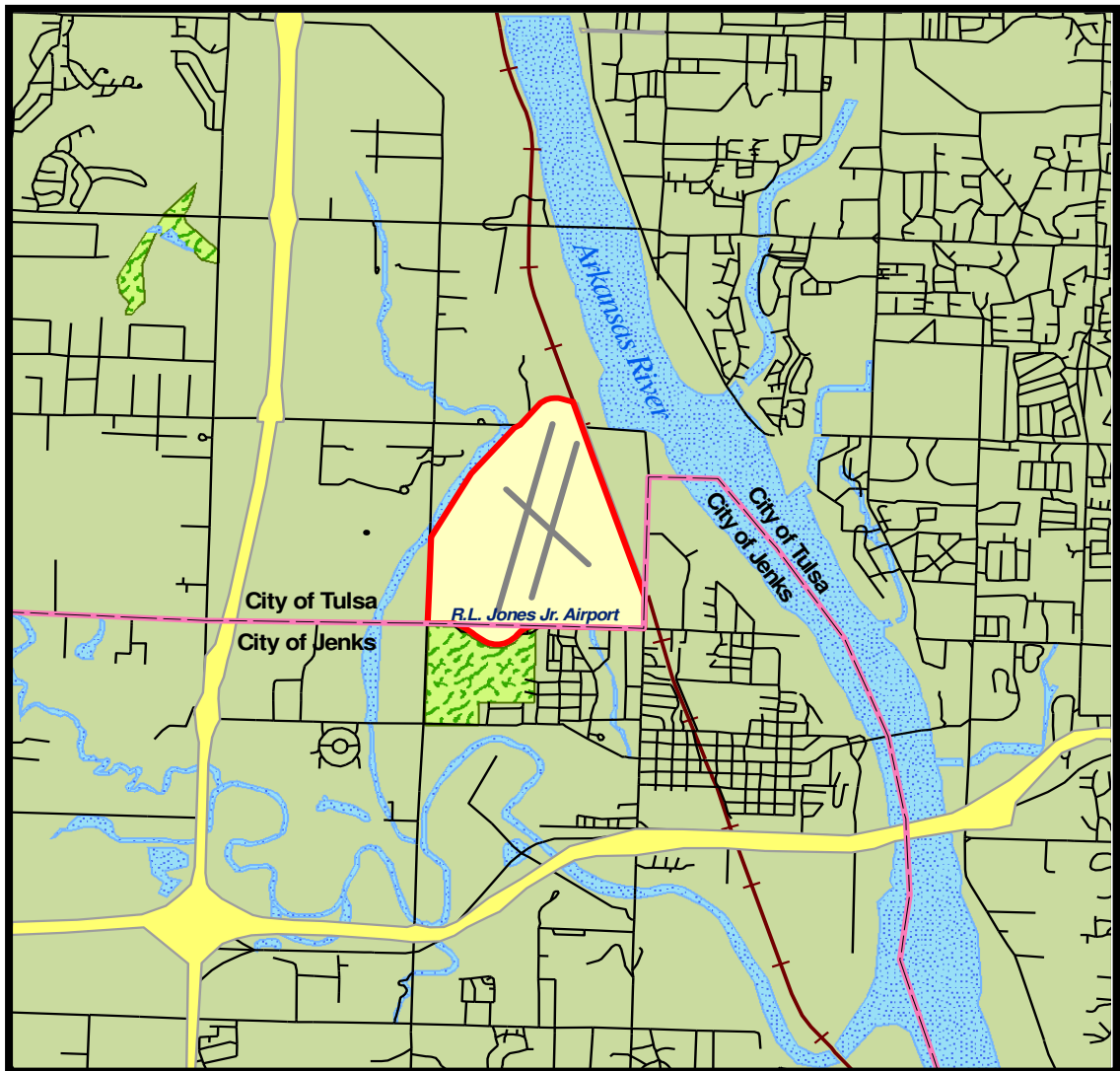


Figure 2. Map of Richard Lloyd Jones Jr. Airport and surrounding area.

RVS, has been maintained. To this day the airport is often referred to by its original name or as Jones-Riverside.

Historical Background

In the 1950's, the City of Tulsa decided to build a secondary airport to be used by general aviation aircraft as a means of relieving congestion at Tulsa Municipal Airport (now called Tulsa International Airport). A national aviation consulting group selected the site for the new airport in February of 1955, proposing an area just north of the city of Jenks on the west bank of the Arkansas River (TAA 2007a). Construction of Riverside began in 1957, and on July 3, 1958 the airport was officially opened with a single 4,000-foot runway aligned roughly north-south (TAA 2007a). Riverside Airport, together with Tulsa Municipal commercial airport, was managed by the Tulsa Municipal Airport Authority, later renamed the Tulsa Airport Authority (TAA).

By 1965, air traffic at Riverside was heavy enough to warrant construction of an FAA air traffic control tower (TAA 2007a). In 1978, Riverside reached its highest number of operations up to that time, accumulating 343,499 landings and takeoffs (TAA 2007a). That same year, the Tulsa Airport Authority changed the name to Richard Lloyd Jones Jr. Airport in honor of the late publisher of the Tulsa Tribune, a long-time Oklahoma aviation booster (TAA 2007a). The airport enhanced its operational capability in 1989 with the addition of an instrument landing system (ILS) for precision instrument approaches (TAA 2007a).

Characteristics of the Airport

Richard Lloyd Jones Jr. Airport is an FAA-designated reliever airport serving private and business aviation for the greater Tulsa area. It was selected for this study partly because of its reliever status. The term “reliever airport” is used to designate the largest, busiest, and most complex general aviation airports. Reliever airports are intended to divert business aircraft and other GA traffic away from congested air carrier airports in large metropolitan areas (NPIAS 2004). Jones is typical of other reliever airports across the country in terms of location and level of service. It is situated in an urban area of 900,000 people (U.S. Census Bureau 2007) and provides a full range of aviation services. Jones has two parallel runways capable of handling small jets, as well as a shorter crosswind runway. It is among Oklahoma’s forty airports (29 percent of the total) considered to be regional business airports capable of handling jets (OAC 2006).

Jones Airport consistently ranks as Oklahoma’s busiest airport (Table III), with more aircraft operations than either of the state’s two major commercial facilities, Will Rogers World Airport in Oklahoma City and Tulsa International Airport. In 2005, it was the fourth busiest GA airport nationwide and ranked as the thirtieth busiest among all airports (FAA 2007a). That year, Jones Airport logged 347,000 operations, or the equivalent of 950 takeoffs and landings in a single day. Because of its high volume of aircraft operations within an urbanized area, it is an ideal venue for exploring the spatial influence of a general aviation airport on surrounding land use. It is assumed that any impact on the surrounding landscape would be more detectable at such a large and active airport. Some representative photographs of the airport and several types of land use within 1,000 feet of it are found in figures 3, 4, 5 and 6. The airport also has a significant



Figure 3. Richard Lloyd Jones Jr. Airport in Tulsa, Oklahoma.



Figure 4. Industrial area (Zone B) within 1,000 feet of the airport boundary (Note: In the distance is an airplane in the traffic pattern, inside yellow circle).



Figure 5. Airplane taking off and about to fly over South Lakes Golf Course (Zone C) (located across 91st Street from the airport).



Figure 6. Airplane taking off near a residential area (Zone F) southeast of the airport (airport buildings are in the background).

economic impact, with a number of aviation-related businesses located on the field. The airport provides employment for some 200 people and generates over \$3.2 million annually (TAA 2007b). Though exact numbers can fluctuate from month to month, about 500 aircraft are based at Jones Airport (JRAA 2007).

Much of the traffic generated at Jones Airport is from flight training being conducted through educational programs such as Spartan College of Aeronautics and Technology and Tulsa Community College's Professional Pilot School, plus flight schools operated by two full-service FBO's⁸ (Christiansen Aviation and Roadhouse Aviation), and other flight schools.

Runway Description

Runway orientation and utilization are influenced by the prevailing winds at a given site. The average wind speed for the Tulsa area is about seven miles-per-hour, but it varies by direction. The strongest winds are out of the south and north, whereas the mildest winds are out of the east and west (OCS 2007). The winds at Jones Airport, like much of Oklahoma, are predominantly out of the south and southeast (OCS 2007; Appendix C). All other things being equal, the wind direction would encourage the majority of approaches over the course of a year to be made on the northern side of the airport and departures on the southern side over the golf course (Figure 7). However, all four instrument approach procedures for Jones have northerly approaches. When weather conditions are not suitable for visual approaches or when aircraft are practicing

⁸ A fixed-base operator (FBO) is a business based on an airport that provides various services for pilots and aircraft. The services offered by an FBO may include such things as fueling, parking, maintenance, flight planning resources, flight training, and aircraft rental, charter, or sales.



Source: Tulsa Airport Authority (2007b)

Figure 7. Aerial photograph of Richard Lloyd Jones Jr. Airport.

instrument approaches, the favored direction for approaches and departures is to the north using runway One-Left (1L), rather than to the south. In addition to the instrument approaches available, runway 1L/19R has 897 more feet available for stopping on landing or accelerating for takeoff, making it the preferred runway for high performance aircraft. This could expose properties at either end of that runway to more of the detrimental impacts from airport operations.

Two operational requirements specific to Jones Airport should enhance the role of runway orientation in affecting land use. First of all, aircraft taking off from Jones are required to continue climbing straight out on runway heading until reaching 1,500 feet MSL⁹ (862 feet above airport elevation) (AOPA 2007a). This requirement causes departing aircraft to overfly land farther beyond the runway ends than normal and also to be at a higher altitude when they begin a turn. As a result, properties beneath the extended runway centerline receive increased exposure to aircraft overflight, while the impact is reduced on properties to either side of the runway. The airport traffic pattern altitudes at Jones are also slightly higher than normal. For light aircraft the traffic pattern altitude is 1,700 feet MSL (1,062 feet above airport elevation) and for heavy aircraft (those over 12,500 pounds) it is 2,100 feet MSL (1,462 feet above airport elevation) (AOPA 2007a). Thus, land underneath the airport traffic pattern, i.e. most of the land on the east and west sides of the airport, is not considered to be significantly affected by aircraft overflight.

⁹ MSL refers to the altitude of an aircraft and is referenced to its height above mean sea level. It is normally measured in feet.

Government Involvement in Adjacent Land Use

United States Federal Government

The Federal Government can influence land use around airports through its policies, programs, and funding priorities. While a number of agencies have an interest in some aspect of airport operations, the FAA is most directly involved. Adherence to its policies in the form of Federal Aviation Regulations (FAR), advisory circulars (AC), and other guidance can result in changes to land use on and adjacent to airports. Grants under the FAA's Airport Improvement Program and other types of government funding for construction projects or modifications can also have consequences for land use (NPIAS 2004).

One of the objectives behind FAA policy is to safeguard the viability of America's airports by ensuring they can continue to be utilized safely and efficiently. This responsibility includes not only the safety of aerial navigation, but the protection of persons and property on the ground from hazards or nuisances stemming from aircraft operations. When deemed necessary, the FAA may issue a recommendation advising against the presence of any object or activity near a public-use airport that is determined to be incompatible (FAA 2007b). To ensure that airports continue to have adequate room for aircraft to operate safely and efficiently, the FAA recommends that airport operators take steps to protect airspace around airports. This may be done by acquiring adjacent properties, revising zoning ordinances, or purchasing aviation easements (FAA 2007b). The main concerns are to: 1) limit the height of objects that may pose a hazard to aerial navigation, 2) prevent urban encroachment on the airport, 3) preclude conflicts related to

noise, and 4) minimize airport-related hazards for those on the ground.

Airport elements should be on airport property to reduce the potential for incompatible land uses that hinder the ability of the airport to operate effectively. This would include the runway-associated zones and areas described in the FAA's advisory circular (AC) entitled "Airport Design" (FAA 2007b). Examples of these runway elements are the Runway Object Free Area (ROFA), Runway Safety Area (RSA), Obstacle Free Zone (OFZ), and the Runway Protection Zone (RPZ) (Figure 8; Appendix D). Portions of FAA-defined imaginary surfaces described in FAR Part 77, "Objects Affecting Navigable Airspace," should also be on airport property (14 CFR Part 77, 2006; Appendix E). In particular, any airport imaginary surface should be under airport control to a distance where its surface reaches a height above the primary surface of at least 35 feet (10 meters), as well as any area that can not be adequately controlled otherwise (FAA 2007b).

State and Local Governments

Compared to federal and local levels of government, state government has the least influence on land adjacent to airports. In Oklahoma, the state agency responsible for aviation is the Oklahoma Aeronautics Commission (OAC). The OAC is involved in planning and developing the state's public airport system, and provides funding for capital improvement projects (OAC 2006).

While federal, state, and local levels of government each have a role in guiding land use around airports, it is the local authorities that arguably have the most direct impact, principally through their development policies and the enforcement of zoning regulations

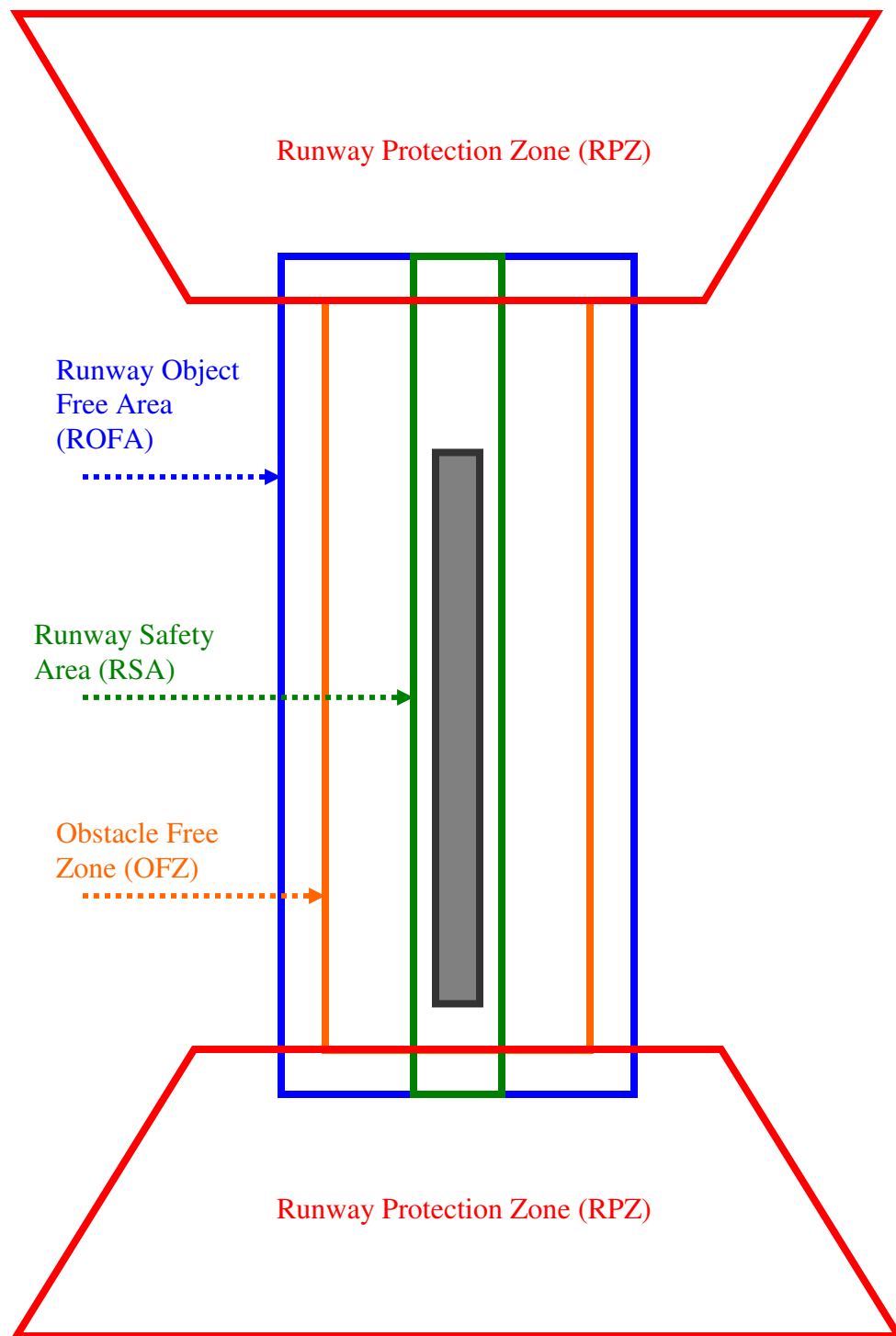


Figure 8. Runway-associated areas (FAA AC 150/5300-13).

(William V. Cheek and Associates 2000). The bulk of responsibility for encouraging compatible land uses around an airport rests with the local zoning authority, in concert with the airport operator. In Tulsa, a variety of local public institutions have influence on land uses. The Airport Zoning Board is responsible for establishing zoning around Tulsa's municipally-owned airports. However, the Tulsa Airport Authority (TAA) is the administrative and operating entity for both publicly-owned airports. Day-to-day development, operation, and maintenance decisions are made by the Tulsa Airport Improvements Trust (TAIT) (City of Tulsa 2006). Since the south and east sides of Jones Airport abut the city of Jenks, the Jenks Planning Commission also plays a role in influencing land use decisions near the airport.

An 18-hole golf course occupying airport property, and underlying the approaches to runways 1L and 1R, is situated within the Jenks city limits, but is operated by the Tulsa County Parks Department (Tulsa County 2006). Other government entities that may have interests in Tulsa's airports are the Tulsa Metropolitan Area Planning Commission (TMAPC), the Tulsa Economic Development Corporation (TEDC), and the Indian Nations Council of Governments (INCOG) (City of Tulsa 2006).

CHAPTER 5

METHODOLOGY

Overview

This chapter begins with a discussion of considerations involved when using the case study research method. It then describes the methods used for addressing the two research questions. For each question, a separate study area around the airport had to be delimited. The dimensions of the two study areas were based largely on FAA standards for imaginary surfaces. A zoning map, city map, and aerial photos were the primary sources of data used in the analysis. A geographic information system was subsequently used to prepare the data and for analysis. The last section addresses the potential for the presence of the Arkansas River floodplain to distort the analysis.

The Case Study Research Method

The research method chosen here for examining the relationship between a general aviation airport and surrounding land uses was the case study approach. In choosing a research methodology, the researcher must consider the suitability of each option. A case study examining one particular airport was the preferred approach by this researcher. One advantage of this method is its ability to aid in distinguishing between a phenomenon being studied (airport influence on land use) and its context (the geographic situation)

(Yin 1993). The busiest general aviation airport in Oklahoma, which also happens to be the most active of any airport in the state, was selected because the influence of such an airport on nearby land use patterns was expected to be more apparent. Data collection for a case study can be extensive, as it draws on multiple sources (Creswell 1998). This case study relied primarily on data collection in the form of maps, aerial photographs, and census data, and was supplemented by ground surveys and interviews.

In some ways, this case study is a departure from the norm. With its roots in clinical psychology and related social sciences, many conceive of the case study approach to research as involving the study of individuals or groups, rather than places or objects (Brown et al. 1999; Creswell 1998). However, the context of the case may involve a physical setting, as with this study (Creswell 1998). In addition, data pertaining to a case typically involves a chronology and may be gathered over a period of time, whereas this study is only concerned with land-use patterns as they exist at present (Creswell 1998).

A case study can take many forms (Bechhofer and Paterson 2000). While this one is quantitative in nature, many case studies involve the collection of qualitative data rather than quantitative (Bechhofer and Paterson 2000; Creswell 1998; Yin 1993). Regardless, the choice of a qualitative or quantitative approach, or a combination of both, depends on the purpose of the research and the questions to be addressed (Brown et al. 1999).

Among the concerns the researcher must bear in mind while conducting a case study are its validity, reliability, and generalizability. Validity has to do with instruments and measures that provide accurate results (Yin 1993). It can be ensured by collecting and analyzing accurate data, selecting appropriate units of analysis, and making sure that the variables measured are the ones intended (Brown et al. 1999). Following a case study, or

sometimes while it is still ongoing, procedures may need to be reevaluated and redesigned, if warranted, in striving for validity (Yin 1993).

Reliability refers to results that are accurate and dependable. It is achieved by being consistent in carrying out procedures and the use of data, and allowing no errors in measurement (Brown et al. 1999; Yin 1993). Reliable procedures and data should always yield the same results (Brown et al. 1999).

Finally, in choosing a case to study and evaluating its findings, one must consider how representative it is (Bechhofer and Paterson 2000). A case study provides detailed information on the unique characteristics of the case, but it also may limit the extent to which findings can be generalized (Brown et al. 1999). There is a possibility that the case study results will not apply to other places, since the contextual variables in one study may differ significantly from the context of other cases (Yin 1993). Narrowing down the characteristics or aspects involved in a case study help to make it more generalizable (Bechhofer and Paterson 2000). Although the findings from this study may reveal common spatial patterns applicable to other busy general aviation airports in various contexts, further research will be required to determine which findings from this case study, if any, are generalizable to other airports.

Dimensions of the Study Area

This section discusses dimensions of the study area and the rationale used in defining them. Determining study area dimensions involved two factors: 1) delimiting inner and outer boundaries, and 2) dividing the area into units for analysis. The first research question addresses the role of the airport boundary in influencing land use, while the

second evaluates the impact of runway orientation. This difference in focus between the two research questions necessitated dimensions of the study area for the second two hypotheses that differed slightly from what was used for the first two hypotheses.

To be of greatest value, the study area dimensions needed to have an appropriate size and shape for capturing affected land uses outward from the airport. The optimal area would encompass all surface areas affected by the airport without including features beyond the affected area. Since the actual extent of the area affected by airport operations was unknown, some basis had to be used for estimating appropriate dimensions that was tied to existing rather than arbitrary standards.

Guidance for determining appropriate dimensions for the study area was found in FAA regulations and standards pertaining to obstacle clearance. To ensure safe and efficient operations at airports, the FAA has delineated several kinds of defined areas and imaginary surfaces providing suitable obstacle clearance on and around airports. Within the FAA's object clearing criteria are seven areas most relevant to this study. Four already noted are described in greater detail in Advisory Circular AC 150/5300-13, "Airport Design," which discusses runway-associated areas and zones (FAA 2007b). These four areas consist of the Runway Object-Free Area (ROFA), the Runway Safety Area (RSA), the Runway Obstacle-Free Zone (ROFZ), and the Runway Protection Zone (RPZ). A descriptive summary of these four areas is found in Appendix D.

The preceding four elements are of limited value for the purposes of this study, however, since they pertain to the runway environment and are mostly confined to airport property. Of greater utility in determining meaningful boundaries are the imaginary surfaces discussed in FAR Part 77 "Objects Affecting Navigable Airspace" (14 CFR Part

77, 2006). This regulation addresses airport-associated imaginary surfaces related to obstructions affecting navigable airspace in the vicinity of airports. Among the five imaginary surfaces described in that regulation, three are useful for this study: the primary surface, the approach surface, and the horizontal surface. A comparison of all seven areas that have been mentioned (the four selected from AC 150/5300-13 and the three selected from FAR 77) may be found in Appendix E.

Runway Classification

Most of these FAA-designated imaginary surfaces are located on airports and some have portions extending beyond the airport; all of the surfaces have something to do with runways. Several were used as the basis from which to develop the configuration of the study area. The dimensions of the imaginary surfaces were determined by the runway classification for each runway at the airport. According to FAR 77, each runway at an airport is classified differently, depending upon its runway category (based on aircraft weight and means of propulsion), the type of approach available or planned (visual, non-precision instrument, or precision instrument), and in some cases, the minimum visibility required (Table IV). A runway equipped with an ILS, such as runway 1L at Jones Airport, is classified as a precision runway. Other runways at Jones best fit the utility description.

Classification of Airport Runways in FAR Part 77		
Type of Approach Planned for Runway	Runway Category	Visibility Restrictions
Visual	Utility*	
	Other than utility	
Nonprecision instrument	Utility*	
	Other than utility	Visibility > ¾ mile
		Visibility ≤ ¾ mile
Precision instrument		

Sources: FAR Part 77; Horonjeff and McKelvey

* Utility runways are intended for propeller-driven aircraft having a maximum weight of 12,500 pounds or less

Table IV. Runway classification system.

Research Question 1

The first two hypotheses were not meant to analyze surfaces on airport property, but only land beyond the airport boundary. Thus, airport property was excluded from the area evaluated. Although South Lakes Golf Course is on airport-owned land, it was included in the analysis since the golf course does not serve an aviation function.

Because H_1 and H_2 are intended to examine the impact of the airport as a whole on surrounding land use rather than just the runways, only the area beyond the airport boundary and extending outward to a distance of 10,000 feet was analyzed, creating an oval-shaped area. An outer limit of 10,000 feet was selected to be analogous to the FAA-designated horizontal surface. Setting the limit at this distance also created an area sufficient to capture spatial influences out to one-half mile (2,640 feet) beyond the airport boundary as stated in H_1 and H_2 , plus any influences that might extend even farther, yet it was limited enough to minimize the inclusion of extraneous territory. The area between the airport boundary and the outer limit was divided equally into twenty 500-foot

concentric rings (or buffers¹⁰). This division struck a balance between: 1) providing sufficient precision to detect changes in the proportion of each land use with changes in distance from the airport, and 2) not being unnecessarily detailed.

Research Question 2

The second two hypotheses address the impact of runway orientation on surrounding land use patterns. Some guidance was taken from several of the imaginary surfaces described in FAR 77 “Objects Affecting Navigable Airspace” in determining the dimensions of the study area and its division into four sections. However, the FAA imaginary surfaces were adapted to suit the needs of this study, even though the nomenclature was retained.

A rectangular area approximating the FAA-defined primary surface and enclosing the two parallel runways was excluded from the analysis, but the surrounding surface within 10,000 feet of its perimeter, including portions of the airport property, was included. Similar to research question one, an outer limit of 10,000 feet was selected to be analogous to the FAA-designated horizontal surface. Setting the limit at this distance also created an area sufficient to capture spatial influences out to one mile (5,280 feet) beyond the airport boundary as stated in H₃ and H₄, plus any influences that might extend even farther, yet it was limited enough to minimize the inclusion of extraneous territory.

Within the study area, four sectors were created to determine how land beyond the runway approach and departure ends was used differently than land falling outside these

¹⁰ A buffer is a zone surrounding a particular map feature and extending outward a specified distance from that feature, forming a band around it. Multiple, concentric buffers at specific intervals around a feature are also possible and are used herein.

sectors. The two sectors aligned with the runway ends are analogous to the FAA-defined approach surface. The other two, encompassing the landscape on either side of the runway, are analogous to portions of the FAA-defined horizontal surface. These are referred to as “side sectors” in this study.

In order to address the second question, four sectors based on FAA guidelines were created as a means of measuring runway effects. The goal in establishing the shapes and dimensions of the four sectors was to match the FAA standards as closely as possible while also satisfying the research goal. In the phase analyzing runway orientation (H_3 and H_4) it was necessary to design the four sectors so they closely resemble the FAR 77 imaginary surfaces, while satisfying the need for ensuring a standardized analysis. The perimeter of the study area was 10,000 feet from any point on the edge of the primary surface. This necessitated several modifications to the FAA dimensions. Out of a desire to satisfy the need for standardization, it was preferable to have the outer boundary of all the sectors the same distance from the edge of the primary surface. To make an accurate comparison among sectors, each was delimited with the same inner and outer boundary, a deviation from FAA standards. Although slight alterations were made to the shapes and dimensions of the FAA imaginary surfaces, resulting in non-standard zones, the FAA nomenclature was retained.

Both the approach surface and the horizontal surface were altered so that they were congruent with the surface of the earth, rather than being an elevated plane (horizontal surface) or a sloping plane (approach surface). As a result of other alterations, the perimeter defining the limits of the study area for H_3 and H_4 extends 10,000 feet from the edge of the rectangular primary surface.

Only the hypotheses under the second research question addressing runway orientation used the three surfaces discussed here. The study area for testing these hypotheses was decided to be within the 10,000-foot buffer of the primary surface. In considering only the two parallel runways and omitting the crosswind runway, the resulting shape of the study area for H₃ and H₄ was something that resembled an oval track stretching about five miles north-to-south, with a width of four miles east-to-west. The exact dimensions were 25,502 feet¹¹ north to south and 21,446 feet¹² east to west.

Partitioning the Study Area for Research Question 2

Primary Surface

Figure 9 depicts the three imaginary surfaces referenced in this study as they apply to runway 1L/19R at R.L. Jones Jr. Airport. This is the longer of the parallel runways and has instrument approaches for runway 1L. The primary surface is a rectangular area centered along the runway centerline and extending 200 feet beyond each end of the runway. Its width is determined by runway classification (Table IV). The two parallel runways at Jones are classified as other than utility runways because they can be used by airplanes over 12,500 pounds maximum gross weight or by jets (14 CFR Part 77, 2006).

The FAA has authorized four instrument approach procedures for Jones Airport. Only

¹¹ The longer runway is 5,102 feet in length. Its primary surface extends 200 feet beyond either end, or 5,502 feet end-to-end. The area examined extends from the perimeter of the primary surface out to a distance of 10,000 feet.

¹² The primary surfaces of the two parallel runways overlap. From the far side of one to the far side of the other, the width is about 1,446 feet. The area examined extends 10,000 beyond this perimeter.

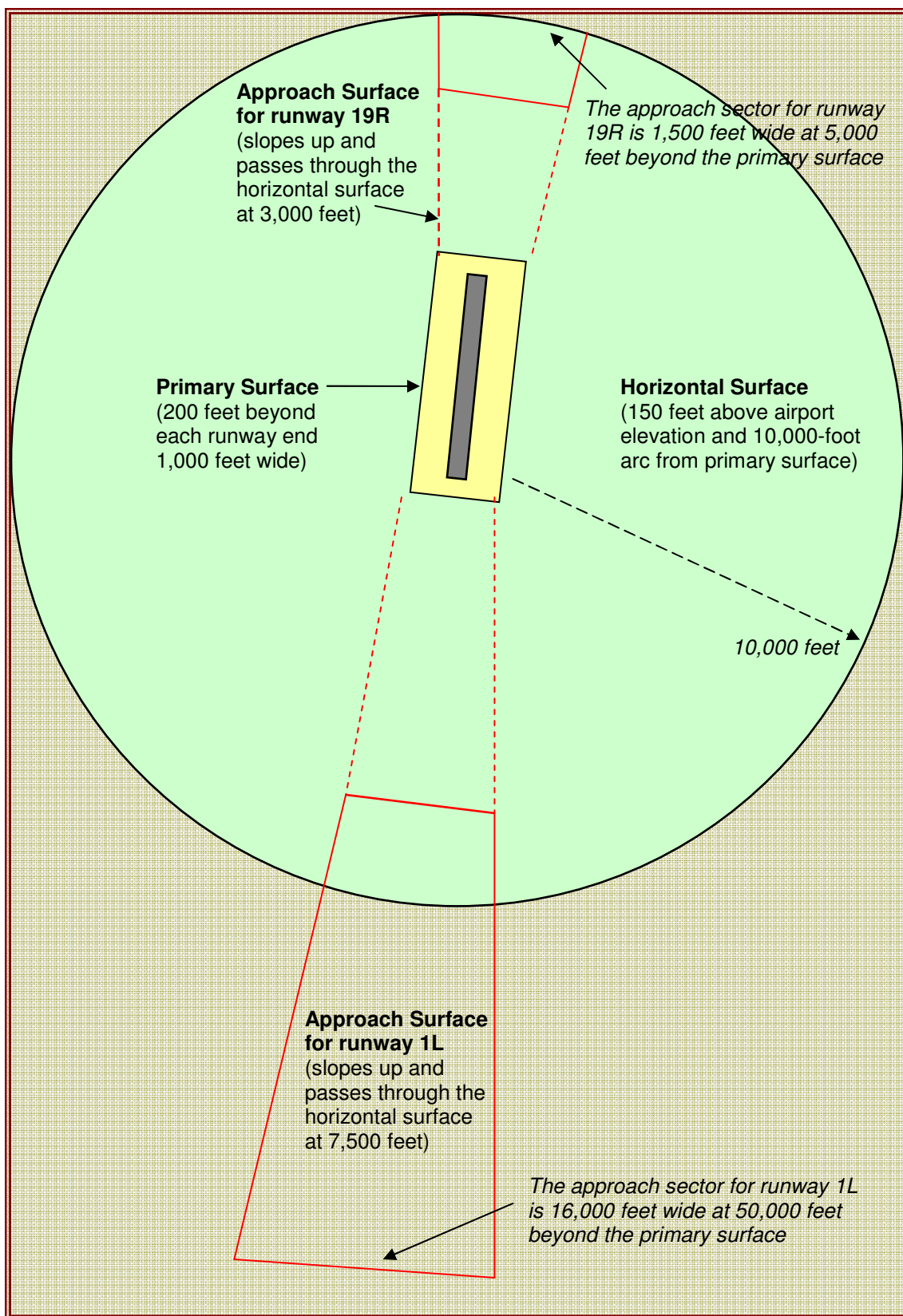


Figure 9. Imaginary surfaces for Jones Airport, runway 1L/19R (Reference: FAR 77).

one of them, the ILS¹³ for runway 1L, is a precision instrument approach. Since this one runway has a precision instrument approach, its primary surface is 1,000 feet wide (14 CFR Part 77, 2006). A precision instrument runway requires a larger safety area due to the more exacting demands of such an approach. As the longest and most capable runway, 1L/19R handles a greater number of larger and noisier aircraft operating at the airport, such as small business and military jets, turboprops, and multi-engine piston-powered airplanes. Furthermore, its utility during adverse weather conditions means it is used more extensively than the other runways. The overall result of these two factors is a greater potential to impact the area surrounding runway 1L/19R.

The shorter parallel runway (1R/19L) is limited to visual approaches only, with the exception of the sidestep maneuver authorized for the ILS runway 1L approach. Being 894 feet shorter than the ILS runway and less suitable for instrument approaches, aircraft utilizing runway 1R/19L tend to be smaller and less capable, resulting in relatively less potential to impact the surrounding area. Also, its primary surface is 500 feet wide – half that of the ILS runway (14 CFR Part 77, 2006). The third runway at Jones is the crosswind runway, 13/31. It is the shortest, narrowest, and least capable of the three runways, and is seldom used. Since its impact beyond the airport is minimal, it was not factored into this study.

Procedures for Drawing the Primary Surface

Since the inner and outer limits of the study area, as well as the dimensions of the

¹³ An instrument landing system (ILS) is a ground-based navigation aid that provides the pilot with both directional and vertical guidance, enabling him/her to descend to lower minimum altitudes, thereby increasing the likelihood of establishing positive visual contact with the runway.

other two surfaces, are based on the size of the primary surface, it was necessary to determine the dimensions of this rectangular surface first. The primary surfaces of the two parallel runways were used as references in creating the study area dimensions for examining H₃ and H₄. For the purpose of this study it was considered desirable to merge the two primary surfaces together and form a single, combined primary surface that would encompass both runways. After the union of the two primary surfaces, the corners of the smaller primary surface were extended to make them even with those of the larger one. The result was one large rectangle encompassing both runways and measuring 5,502 feet in length and about 1,446 feet in width. This is the distance from the western edge of the ILS runway's primary surface to the eastern edge of the visual runway's primary surface. No analysis was carried out on any land within this merged primary surface.

Once the primary surface was created in ESRI's¹⁴ ArcMap¹⁵, it was used as the basis for establishing the inner and outer boundaries of the study area (ESRI 2005). Then, after delimiting the boundaries, the four sectors for testing H₃ and H₄ were created. These sectors are derived from the approach and horizontal surfaces. The inner boundary of the study area conformed to the perimeter of the primary surface, while the outer boundary was delimited by a buffer extending 10,000 feet beyond the perimeter. Two trapezoids representing the approach surfaces, north and south, were created. Finally, two side sectors situated on the east and west sides of the runways between the approach surfaces

¹⁴ Environmental Systems Research Institute, Inc. (ESRI) is the company that developed and sells ArcGIS 9.1 (which includes ArcMap) and other geographic information system (GIS) software, as well as related applications.

¹⁵ ArcMap is a software application used for map creation and spatial analysis. It is the primary application bundled in ArcView, which is the most basic of three functional levels available with ArcGIS 9.1 Desktop. The ArcGIS product line consists of integrated suites of GIS applications created by ESRI.

were created from the remaining areas.

Approach Surface

The approach surface is a trapezoid-shaped area off each end of a runway and centered along the extended runway centerline (Figure 9). Its inner edge abuts the end of the primary surface at 200 feet beyond the end of the runway and shares the same width at that location. From where the primary surface ends, the approach surface extends upward at an angle and widens uniformly until reaching its outer limit, where it reaches its maximum width (14 CFR Part 77, 2006).

Like the primary surface, the dimensions of the approach surface are determined by runway classification (Table IV). Since precision approaches are the most demanding, the approach surface for a precision instrument runway, such as Jones Airport's runway 1L, has the largest dimensions. The width at the narrow end abutting the primary surface is 1,000 feet. From there, its length extends 50,000 feet outward. At this outer limit the trapezoid reaches its maximum width of 16,000 feet. All other runways at Jones have visual approaches only and are not as restrictive. Therefore, their approach surfaces are only 5,000 feet long, with outer edges that are 1,500 feet wide. While the FAA standards were used as a benchmark, the requirements of the study necessitated several alterations in the dimensions of the approach surfaces.

Inner Width

The inner width of any approach surface always corresponds to the width of its primary surface. The width of this inner approach surface was increased to match the

non-standard width of the altered primary surface, which is about 1,446 feet. This wider than normal primary surface was the result of merging the two primary surfaces associated with the parallel runways to make a single larger one from which the approach and horizontal sectors would be based.

Length

The 50,000-foot length applicable to a precision runway was considered excessive for the needs of this study. Instead, a length of 10,000 feet was used. The distance of 10,000 feet is significant for three reasons: 1) it is the distance at which the approach surface for a precision approach has a slight change in slope¹⁶, 2) it is the distance marking the outer limit of the approach surface for a non-utility runway having a non-precision instrument approach, and 3) it matches the outer limit of the horizontal surface, which is discussed in the next section.

Outer Width

Although the length of the approach surface would be compressed to 10,000 feet, it was decided to retain the 16,000-foot outer width, rather than narrowing it proportionately. Doing so resulted in a wider approach surface that more than doubled the area that would have been covered by it. The advantage of widening it was that it incorporated more of the area where aircraft fly at low altitudes as they maneuver for

¹⁶ From the end of the primary surface, the approach surface extends outward for the first 10,000 feet of horizontal distance at a slope of fifty to one, meaning that for every 1,000 feet outbound, the slope rises 20 feet. Beyond 10,000 feet, the slope steepens slightly for the remaining 40,000 feet at forty to one (i.e. for every 1,000 feet outbound, the slope rises 25 feet).

landings and departures. Increasing the area of the approach surface also reduced the disparity in sizes between the approach and horizontal surfaces for a better comparison.

A second modification to the outer width of the approach surface involved rounding the end segment. Rather than using a straight line segment to delineate the outer width of an approach sector, it was rounded to form an arc congruent with the 10,000-foot boundary based on the primary surface, which was also the outer limit for the horizontal surface (i.e. side sectors). Doing so resulted in a smoothing of the outer boundary.

Horizontal Surface

With the primary surface and the two approach sectors delimited, the horizontal surface (i.e. side sectors) could be determined. The FAA defines the horizontal surface as an imaginary horizontal plane 150 feet above the airport elevation (14 CFR Part 77, 2006). The radius of each arc delimiting the horizontal surface is 10,000 feet for precision instrument runways, such as Jones Airport's runway 1L. All the other runways at Jones (runways 19R, 1R/19L, and 13/31) use a 5,000-foot arc.

As was the case with the primary and approach sectors, several alterations in the layout of the horizontal sector were made to adapt it better to suit the needs of the study. First, since the focus is on land use within each sector, the floor of the horizontal surface was made synonymous with the surface of the earth. This also agrees with the parameters of the other imaginary surfaces. Second, only the merged primary sector associated with the parallel runways was used for determining the boundaries of the horizontal surface. Normally under FAA standards, the perimeter of the horizontal surface would have been determined based on the standards for each primary surface for all three runways. Third,

the outer boundary is described by all points that are 10,000 feet from the perimeter of the primary surface.¹⁷ Finally, only those portions of the horizontal surface outside the approach sectors were used, and designated as the east and west side sectors. With the northern and southern approach sectors having been created, the perimeters of the remaining areas on the east and west sides of the primary surface were digitized. The end result of these operations was the creation of four sectors—two approach sectors (north and south) and two side sectors (east and west), each based on the imaginary surfaces described in FAR Part 77 (14 CFR Part 77, 2006).

Research Steps

Data Collection

A geographic information system (GIS) utilizing ArcView software was used for data entry, spatial analysis, and display (ESRI 2005). ArcView is the most basic version of the ArcGIS 9.1 Desktop integrated suite of GIS applications. A GIS is a combination of computer hardware and specialized software that facilitates the storage, manipulation, and analysis of spatial information. It is a powerful tool for analyzing and revealing spatial patterns and relationships, and is commonly used for exploring land use patterns.

The core issue within this study was an evaluation of land use and population density in the vicinity of an airport. Several studies have employed GIS in ways that are similar to the approach proposed for this study. For example, GIS was utilized for analyzing

¹⁷ By comparison, FAR 77 specifies that the perimeter of the horizontal surface is delimited by rotating arcs of specified radii from the midpoint of each primary surface end for each runway, then adjacent arcs are connected by lines tangent to those arcs, thereby delimiting its area (14 CFR Part 77, 2006).

changes to cultural landscapes in southern Germany (Bender et al. 2005). After areal units were digitized, GIS was used to integrate different types of data, to analyze land usage, to calculate the proportion of each land use type, and to determine factors influencing land use changes. The study found this approach useful for analyzing land-use changes, especially for planning and nature conservation purposes. GIS has been used in other ways, such as to analyze changes in land-use patterns in the Pearl River Delta of southern China through the categorization of land use types (Li and Yeh 2004). That approach employed definitions for land uses that are similar to the ones needed in this study using a method that classified land into nine categories. Srinivasan (2002) used a GIS to quantify several neighborhood characteristics, including land use and boundaries. He found GIS useful for organizing spatial data, quantifying spatial characteristics, and classifying spatial differences along a continuum of characteristics (Srinivasan 2002).

Land use data for this study was assembled by combining and cross-referencing data from a variety of sources, such as maps depicting land use, settlement, and buildings. Relevant sources included a zoning map (Appendix G) produced by the Indian Nations Council of Governments (INCOG 2006). This map is used by the Tulsa County Assessor's Office and local planning authorities. Other helpful sources included a city map of Tulsa and Jenks, and U.S. Geological Survey topographic quadrangles (1:24,000 scale). Additional sources helpful for determining land use were zoning and building ordinances, interviews with airport and county officials, and a field-level reconnaissance of the study area. Data for representing population density was obtained from the U.S. Census Bureau.

The base map used for digitizing land-use zones was created from a composite of

several digital orthographic quarter-quadrangle (DOQQ) aerial photographs in the georeferenced Tagged Image File Format (GeoTIFF), which were produced by the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP). The aerial photographs covering the study area were the Jenks 2, Jenks 4, Sapulpa North 1, and Sapulpa North 3 quarter-quads (NAIP 2003a and 2003b). An advantage of using a digital orthophoto is that the data has been corrected for distortions. In light of that fact, aerial imagery (Appendix F) was used for digitizing rather than a county assessor's zoning map (Appendix G), because the digital photos are considered to be more precise and have the capability to reveal more detail on the landscape.

Land-use data was captured through on-screen digitizing. For the sake of simplicity, contiguous parcels containing identical values were aggregated and treated as single parcels. Various polygon-shaped census blocks for which population densities have been determined already existed and simply needed to be downloaded from the U.S. Census Bureau.

Multiple buffers and sectors were created using GIS as a means of analyzing spatial variation in both land use and population density. Buffers around features normally have equal spacing to ensure uniformity of data and to define successively greater distances outward from the airport boundary. ArcView's statistical operations were used to determine the percentage of a land-use type (or population density) within each buffer. Its ability to find areas enclosed within other areas proved especially valuable.

A research methodology outlines how research questions are to be evaluated. Both the steps taken and the rationale behind those steps are important. It may be helpful at this point to remind the reader of the hypotheses being tested and to explain explicit steps

used in testing each.

Research Question 1: In what ways does land use change with increasing distance from a general aviation airport?

First hypothesis (H_1): The proportion of residential, school, and other highly noise-sensitive land uses (Zone F) increases with increasing distance from an airport boundary, up to a distance of one-half mile.

The FAA groups land uses into five categories according to similar types of uses rather than on the basis of sensitivity to noise. The categories are residential, public use, commercial use, manufacturing and production, and recreational (FAA 2007b). Within each category are land uses having varying sensitivity to noise. The land-use classification scheme used in this study draws from FAA recommendations, but is organized differently. This was done because of specific questions being asked. Each noise level was assigned all land uses compatible with it, thereby consolidating all land uses with the same maximum noise level into one land-use zone. By contrast, the FAA sorts all land uses into broad land-use categories and lists various maximum noise levels recommended within each category.

For the purposes of this study it was not important to group similar kinds of land uses. Rather, the study used FAA noise level recommendations to represent the aggregate of all airport operational factors influencing land use around airports. Since aircraft noise is the single most important factor and is accompanied by other factors associated with aircraft operations (pollution and hazards), noise was used as the basis for creating the six land-use zones (Table V). Also, the FAA has existing guidance relating noise levels to

appropriate land uses. Each land use in the table is listed only in its highest recommended decibel band. The general trend expected was for land use to transition from predominantly Zone A activities (least noise sensitive) close to the airport to Zone F activities (most noise sensitive) farthest from the airport.

Land-use Zones					
A	B	C	D	E	F
Agriculture	Industry and utilities	Offices and stores	Hospitals	Nature exhibits and zoos	Residential
Water and floodplain		Government services	Churches		Hotels and lodgings
Transportation		Golf courses	Parks		Schools

Table V. The six land-use zones created for this study.

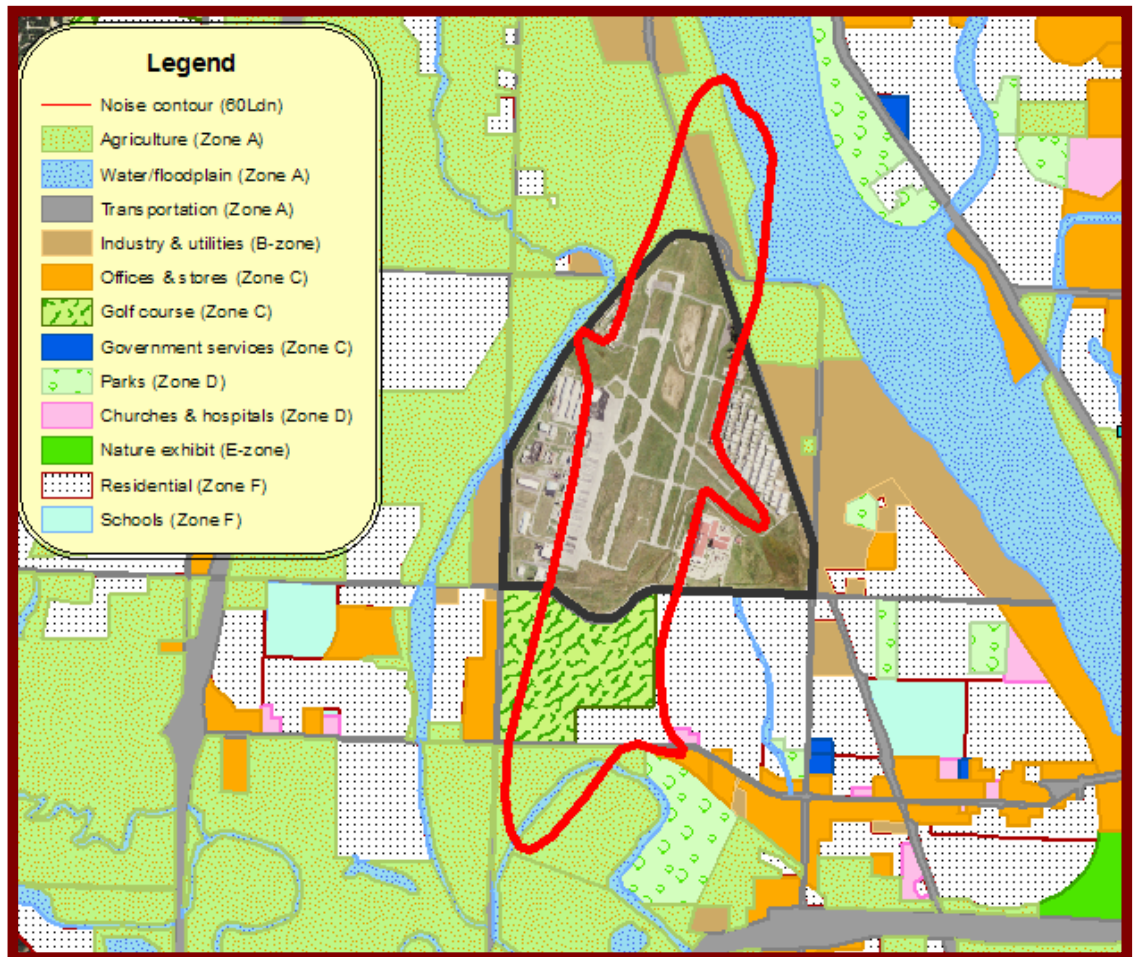
Appendix H shows a detailed comparison among the six land-use zones created for this study and the five FAA land-use categories. The land-use zones are listed in order of increasing noise sensitivity. The five land-use categories mentioned by the FAA are listed across the top of the table. Appendix I provides a comparison of the six land-use zones created for this study and City of Tulsa zoning districts.

For testing H_1 , all land uses within 10,000 feet of the airport were sorted into one of the six zones corresponding to the FAA's guidelines on noise sensitivity. Grouping land uses into several categories was done following methods described by Li and Yeh (2004). Multiple polygons corresponding to the six zones were placed in a data layer by creating an ESRI shape file (hereafter referred to as a shapefile) and performing on-screen digitizing using the DOQQ as a reference.

Although Jones Airport noise contours depict nothing greater than 70 dB, it was

expected that areas closest to the airport would be the noisiest. As a result, H₁ anticipates that the most noise-sensitive land uses (Zone F) would tend to be pushed farther away than other uses. Figure 10 depicts the approximate 60 decibel L_{dn} noise contour line that was projected in 1987 to be in existence by 1993 (Barnard Dunkelberg and Company 1987). The 60 dB contour delimits an area of marginal sound compatibility for all land uses. By its association with aircraft operations, this noise contour line would also suggest that the area within its boundary has more exposure to potential hazards and to pollution resulting from aircraft operations. All land uses outside the contour line were considered compatible, as well as inside the line up to 65 dB. Beyond that, some land uses are no longer suitable, beginning with residential areas, school sites, and hotels (Zone F). It should be noted that north of the airport, all land uses with an L_{dn} of 60 dB or more are classified as Zone A and B, the least noise sensitive categories. The equivalent area south of the airport likewise consists predominantly of less noise sensitive uses that also are not likely to have large concentrations of people, such as agriculture, water and floodplain, and recreation (golf course).

All geographic surfaces in the study area were categorized into one of the six zones and digitized as multiple contiguous polygons. Once all the land-use polygons were entered into a feature class, ArcView was used to create buffers around the airport at 500-foot intervals, beginning at the airport boundary (Figure 11). The outermost buffer extended out to a distance of 10,000 feet beyond the primary surface, resulting in a total of twenty buffers surrounding the airport boundary. A distance of 10,000 feet from the airport property line was deemed a sufficient range to capture any airport-induced land



Source: Barnard Dunkelberg and Company

Figure 10. Noise contour line showing the 60-decibel (dB) yearly day-night average sound level (L_{dn}).

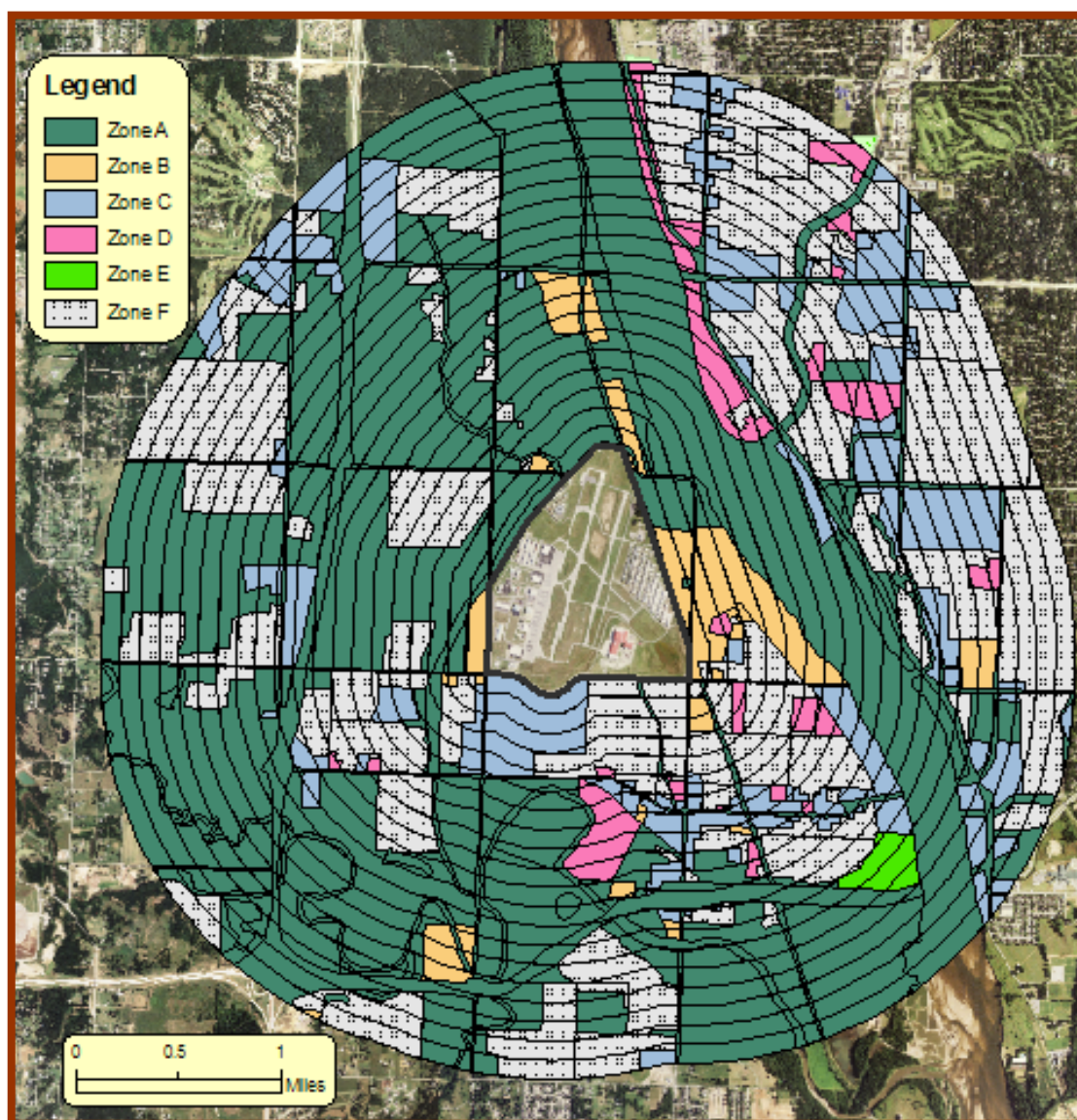


Figure 11. For H_1 : Twenty 500-foot buffers superimposed over six land-use zones.

use change, since this distance includes the maximum extent of the 60 L_{dn} noise contour (Figure 10).

After the buffers were created around the airport, the proportion of each land-use zone within each buffer was determined. Since there was uncertainty about the existence of a progression of land uses or how far out from the airport they extended, it was determined that a constant increase in the proportion of Zone F land use moving outward towards the outer limit would lead to acceptance of the hypothesis.

In discussing the use of GIS for analyzing neighborhood-sized areas based on U.S. census data, Schlossberg (2003) warns against the different results obtained from applying various combinations of spatial analysis techniques and census unit scales. His recommended methodology when extracting spatial data under a buffer is to use the proportional split method. This technique involves determining the proportion of census data in a census zone equivalent to the amount of that zone in the buffer or sector being examined. For example, if a census zone had 2,000 people in it and 15 percent of the zone was in the areal unit being examined, then 15 percent of that population, or 300, would be considered. Following Schlossberg, this study employed the proportional split method.

Second hypothesis (H_2): Population density increases with increasing distance from an airport boundary, up to a distance of one-half mile.

To test the second hypothesis, census block boundaries obtained from U.S. Census Bureau shape files were utilized. Schlossberg (2003) recommends using the smallest areal unit possible consistent with the needs of the research. Portions of about 500 census blocks are located within the 10,000-foot buffer or the four sectors used to address H_4 .

These individual blocks make up twenty-eight census block groups that are completely or partially within the study area.

In addition to block boundaries, population density for each block within the study area was obtained from the U.S. Census Bureau and entered into the GIS database. Once this was done, buffers surrounding the airport boundary were overlaid on the census blocks and the proportion of each population density range within a given buffer was determined (Figure 12), along with an average population density for each buffer. This was done by weighting the density range according to its proportion. Since one-half mile equals 2,640 feet, the minimum distance to meet the requirements of H₂ fell within the sixth buffer (the band from 2,500 to 3,000 feet from the airport boundary). Thus, if the first six buffers had a successive increase in population density, H₂ would be accepted.

Research Question 2: To what extent does runway orientation influence surrounding land use?

Third hypothesis (H₃): The proportion of residential, school, and other highly noise-sensitive land (Zone F) underlying the approach and departure paths of the primary runway is at least ten percent less than those same land use types at an equivalent distance in areas which are not underlying such flight paths, as far as one mile beyond either end of the runway.

It was expected that such a trend exists largely because of noise levels, but also as a result of safety and environmental concerns. The airport location may have been selected partly in an attempt to minimize these negative factors, and current land use patterns are a result of zoning policy and personal choice. Retaining this hypothesis would confirm

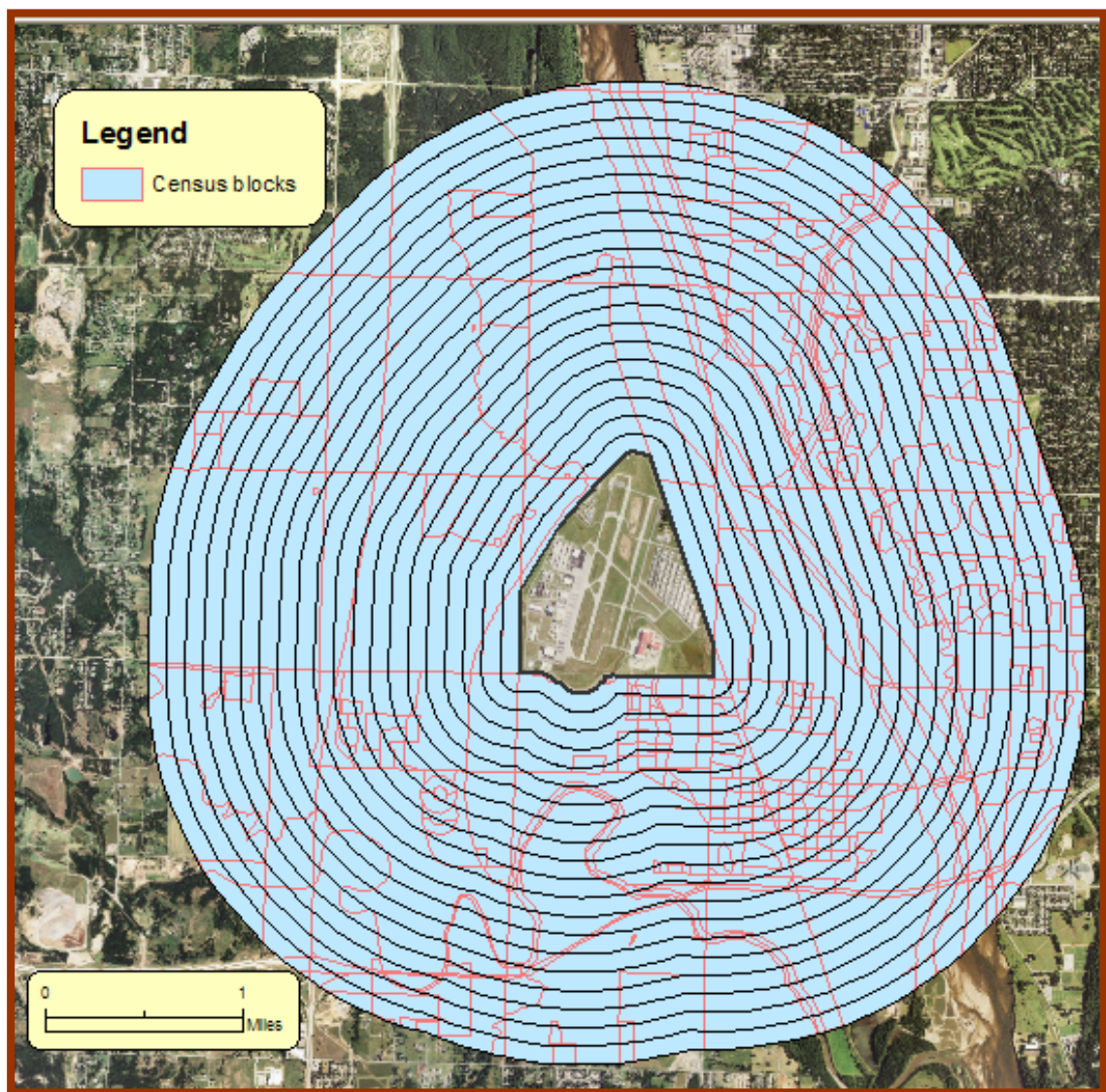


Figure 12. For H_2 : Twenty 500-foot buffers superimposed over census blocks.

these assertions and establish a baseline for comparisons at other airports. One possibility is that current land use patterns in turn are effective in facilitating the current high level of aircraft operations.

As stated previously, to investigate the impact of runway alignment for H₃ and H₄, a primary surface was created around the two parallel runways and four sectors were created to facilitate comparisons. Two of the sectors extend from either end of the runway outward to 10,000 feet. Although Haywood's (1999) study of tram routes did not specify how far outward from the route that land use continued to be affected, he drew his boundaries at 400 meters (1,312 feet, or about one-fourth of a mile) on either side of the route. The other two sectors on either side of the primary surface are larger in area but are likewise identical and extend outward to 10,000 feet from the edge of the primary surface. These sectors allowed for land use patterns and population densities underneath the approach/departure ends of the runways to be compared with those off the sides of the runways.

For testing H₃, the same six land use zones used for hypothesis one were used again. After all four sectors were drawn, the percentage of each zone type within each sector was determined and compared with the other three sectors, with special attention given to the proportion of Zone F (Figure 13). If the land off both ends of the runway had at least ten percent less of the most noise-sensitive land uses such as residential and schools, compared with land to the sides of the runway, the hypothesis would be accepted.

Fourth hypothesis (H₄): Population density underlying the approach and departure paths of the primary runway is at least ten percent less than densities at an equivalent distance in areas that are not underlying such flight paths, as far as one mile beyond

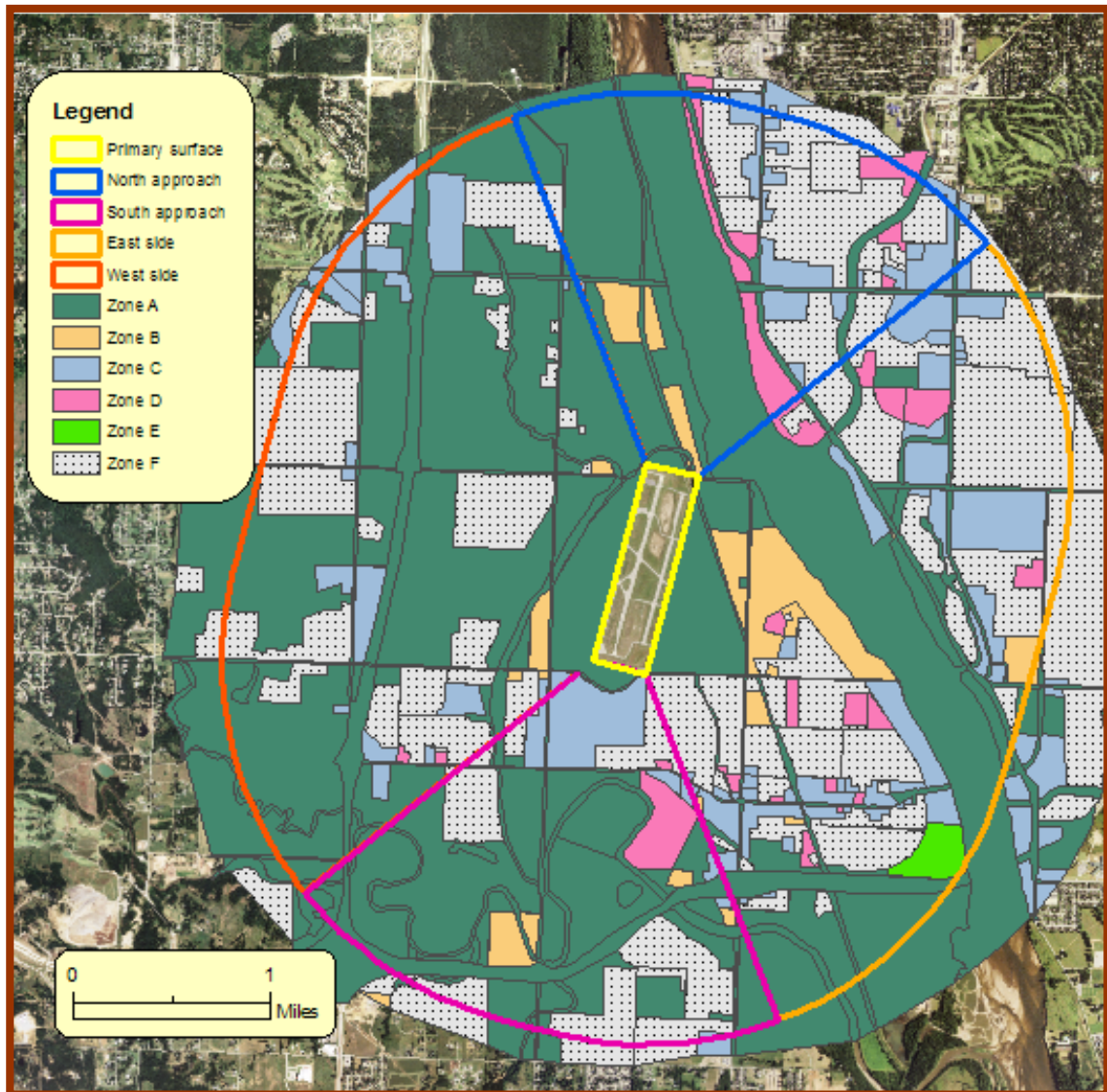


Figure 13. For H_3 : Four sectors superimposed over six land-use zones.

either end of the runway.

To test the fourth hypothesis, the same four sectors used for H_3 were superimposed on the population density data from H_2 (Figure 14). The average population density within each of the four sectors was determined, as was done with the twenty buffers in H_2 , and compared with the other three sectors. If the land beyond the ends of the runway had at least a ten percent lower population density than the sectors on the sides of the runway, the hypothesis would be accepted.

Data Preparation

Land-use Zones (H_1 and H_3)

To test both H_1 and H_3 , the land-use zones needed to be digitized from data contained on the aerial photographs. Six separate shapefiles were made, one for each land-use zone. In the next step, each zone was intersected with the buffer feature class (in the case of H_1) or the sector feature class (in the case of H_3), resulting in a newly-created intersect feature class for each of the land-use zones.

After completing data input for the first research question (H_1 and H_2), some modifications had to be made to the dimensions of the study area to answer the second research question (H_3 and H_4). For one thing, since the 10,000-foot boundary was measured from the smaller rectangle of the primary surface rather than the larger airport boundary, both the inner and outer dimensions of the second study area are generally closer in to the runways and are shaped differently. Thus, although all the land-use zones used for H_1 were copied and used for H_3 , the areas considered between the two were slightly different.

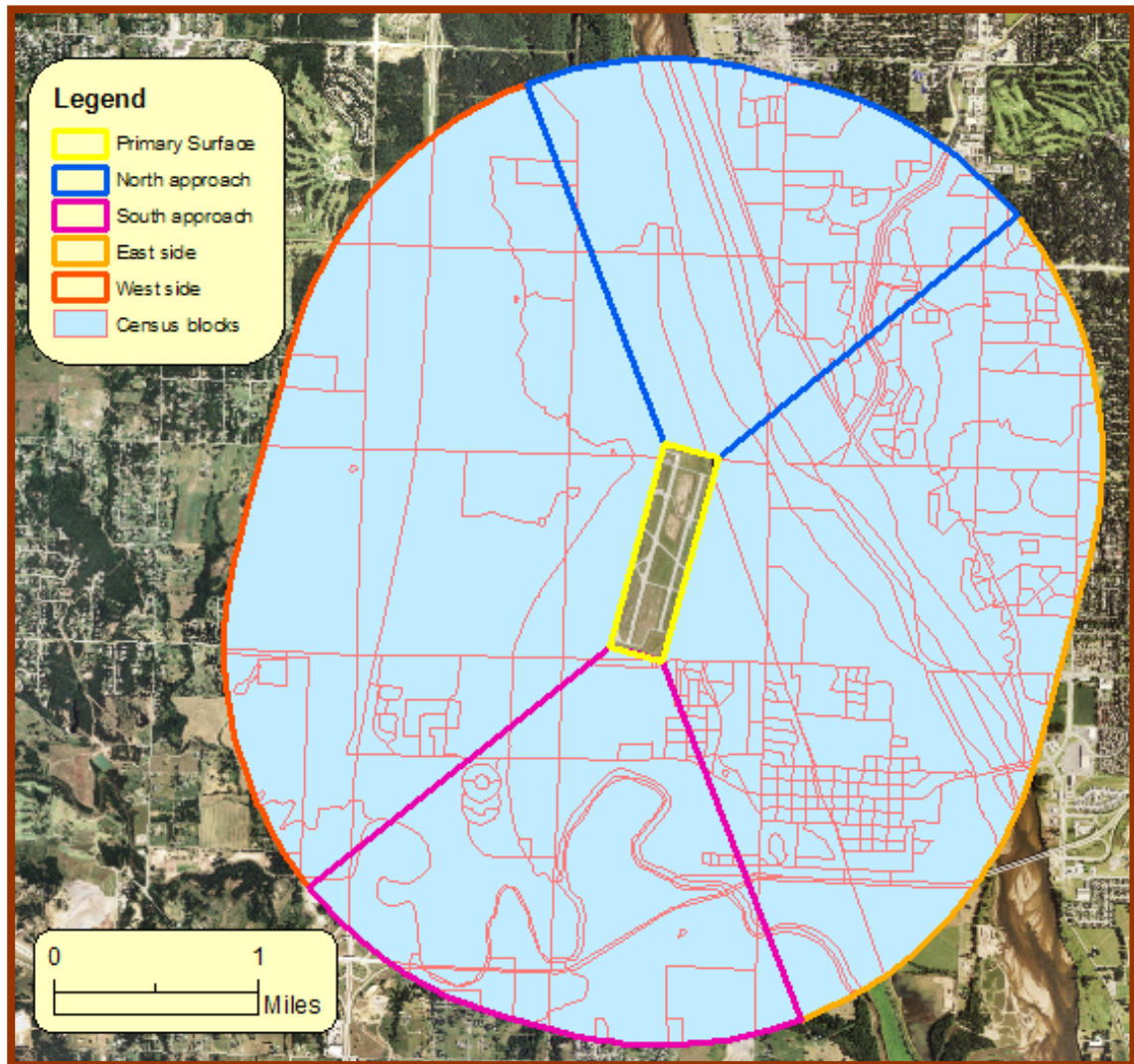


Figure 14. For H_4 : Four sectors superimposed over census blocks.

In addition to the six land-use zone files, a seventh shapefile combining all land-use zones into one feature class was created, resulting in a master feature class. Once all the land-use zones were combined into a single shapefile, it could be intersected with the shapefile containing the twenty 500-foot-interval buffers (H_1) or the four runway sectors (H_3). To address H_1 , all land-use zones were intersected with the twenty buffers to create a new shapefile having both elements.

The next step was to create a feature class having all four sectors merged into one shapefile, which could be used for evaluating the influence of runway orientation for H_3 and H_4 . Unlike the buffers used for H_1 and H_2 , which were intended to capture the effects of distance from the airport boundary, the sectors used for H_3 and H_4 were intended to capture the effects of direction relative to the parallel runways. Thus, for H_3 , all land use zones were intersected with the four runway sectors. The first step was to create an all-zone feature class that included the portion of airport property being examined. With all of the land-use zones merged into a single feature class and the four sectors (H_3) merged into a single feature class, the next step was to intersect the two shapefiles, resulting in a new feature class that could be used for determining proportions of each land-use type within each of the four sectors. This was done using ArcMap's intersect function, following methods discussed previously. The resulting attribute table had 971 records, one for each parcel created. It should be noted that some of these parcels were tiny fragments of land.

The attribute table that resulted from intersecting the master zone file with the buffer/sector file was then exported into a spreadsheet where the data could be manipulated and the proportions of each land-use zone within each of the twenty buffers

(H₁) or four sectors (H₃) could be determined. All parcels exported into the spreadsheet were sorted according to their respective buffer/sector. Then, within each buffer/sector, the total area of each land-use zone was determined.

Population Density (H₂ and H₄)

As another approach to mapping land use, H₂ and H₄ necessitated the use of U.S. Census population data rather than the six digitized land-use zones created for this study. The second hypothesis examines how population density varies with increasing distance from the airport, while the fourth hypothesis examines how population density varies according to its bearing from the runways. The most appropriate enumeration area for the purposes of this study was determined to be the census block. Of the various levels of detail available (tract, block group, or block), the census block data was selected because it is the smallest census unit and provides the greatest level of precision (Schlossberg 2003).

Hundreds of census blocks were located within the study areas. For dividing the study areas into units for analysis, H₂ uses the same twenty 500-foot buffers that were created for H₁, and H₄ uses the four runway-related sectors created for H₃. For each hypothesis, the census blocks were intersected with their respective areal unit (buffer/sector), creating a new file reflecting variation in population densities within each unit. Each record in the resulting attribute table represented a parcel created from the intersection of census blocks (or portions of them) with a buffer (H₂) or sector (H₄). With this information for each buffer/sector, the average population density could be determined. Because the area of a census block is expressed in square meters within the original attribute table, the

parcels created in the attribute table of the intersect shapefile were likewise measured in square meters. To determine the population per square mile for each parcel, the metric parcel areas were subsequently converted to square miles.

Average Population Density by Weighting

To determine the average population density for a given buffer (H_2) or sector (H_4) the proportional split method was used. The population densities within the areal unit were weighted according to their proportion within it (Schlossberg 2003). Thus, for each parcel within a given buffer/sector, its population density was multiplied by its proportion of area within the buffer/sector. Then, the weighted densities for all parcels were added to compute an average population density for the entire buffer/sector.

Arkansas River Channel

Before leaving this chapter on methodology, it should be noted that there was a potential issue concerning the effect of the Arkansas River and its associated floodplain on the analysis. The Arkansas River, which flows from the northwest to the southeast, together with its floodplain, may have skewed the outcome of some of the findings. Most cities must contend with floodplain areas that restrict land-use options, constrain construction, and reduce property values. A busy airport can have much the same effect, though for different reasons. In areas where an airport and floodplain are in close proximity, determining the extent to which each has contributed to nearby land-use patterns may prove difficult. The Arkansas River floodplain is a large natural feature not affected by airport operations and is therefore not zoned in accordance with distance or

direction from the airport. Its western extent is about a half mile from all three runways. The result is that within the middle buffer zones, the amount of land use classified as water and floodplain (within Zone A) may be disproportionately high. This may be less serious than it seems if one considers that: 1) the Arkansas River and its associated floodplain is divided among about a dozen buffers, reducing its impact on any one, 2) the relative proportion of river and floodplain become less with increasing distance from the airport due to the larger area encompassed by each successive buffer, 3) water and floodplain is just one of several sub-zones within the Zone A, along with agriculture and transportation, and 4) areas lying in floodplain are offset by less agriculture and transportation. Therefore, the total for Zone A should not be considerably different than it would be without the presence of the river. Thus, even without the presence of a large river near the airport, much of that land would be classified as Zone A. Considering these factors, the potential for the river to skew the results was acknowledged, but considered minimal and acceptable given the desirable characteristics of the airport for the study.

CHAPTER 6

FINDINGS

Overview

This chapter reviews the results from testing each of the four hypotheses, addressing which were retained and why. Subsequently, it presents six major research findings for this airport. Among the most significant of these findings is the approximate range of the airport's influence, which was found to be 2,000 feet.

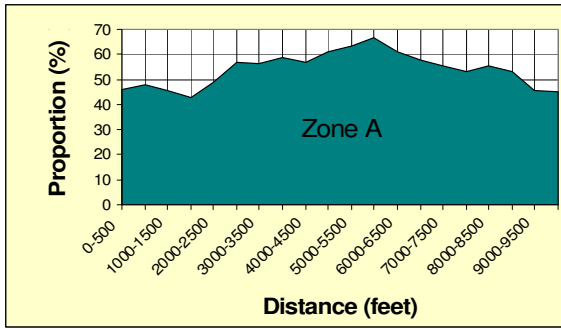
Summary of Results

Research Question One: Influence of Distance

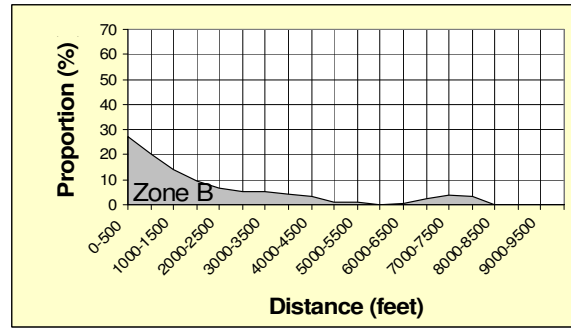
The first research question aimed to shed light on the ways land use changes with increasing distance from a general aviation airport. Thus, the first set of two hypotheses examined the extent to which proximity to an airport boundary influences surrounding land-use patterns. Testing of the first two hypotheses confirms assumptions set forth in this study. Figure 15 provides a comparison of proportions of each of the six land uses as a function of distance from the airport boundary.

Hypothesis One (Airport Boundary and Land Use)

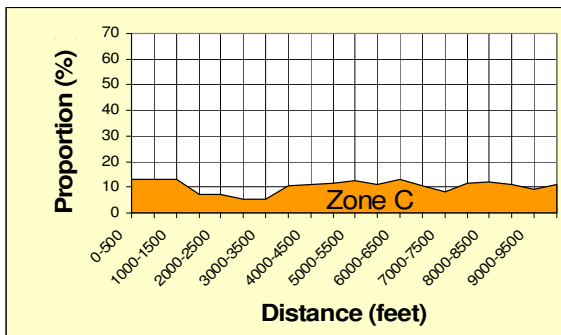
The first hypothesis states that the proportion of residential, school, and other highly



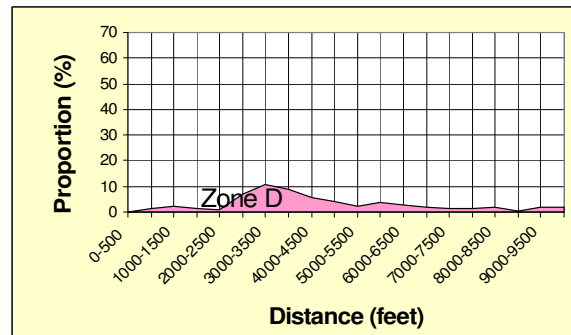
*Agriculture, water and floodplain,
and transportation*



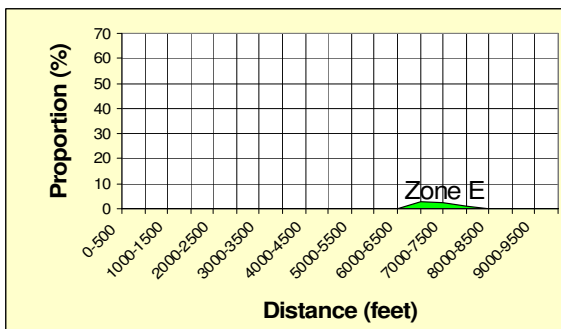
Industry and utilities



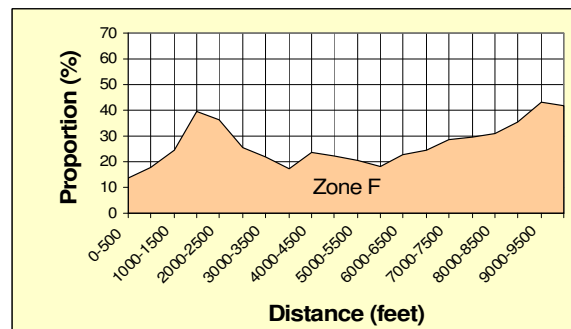
*Offices, stores, government
services, and golf courses*



Hospitals, churches, and parks



Nature exhibits and zoos



Residential, hotels, and schools

Figure 15. Proportion of each land-use zone as a function of distance from the airport.

noise-sensitive land uses (Zone F) increases with increasing distance from an airport boundary, up to a distance of one-half mile. Figure 15 provides perspective on how Zone F fits with the other five land uses by depicting their proportions as a function of distance from the airport. Testing of H_1 confirmed that the proportion of residential, school, and other highly noise-sensitive land uses (Zone F) does in fact rise with increasing distance from the airport boundary, at least out to a distance of one-half mile. In other words, the results showed that with increasing closeness to the airport, the amount of noise-sensitive land use declines. Despite its smaller size compared to a major commercial service airport, a look at the spatial patterns of residential areas (Zone F) around Jones Airport supports Carlsen's (2002) observation that airport operations discourage the development of housing. While the proportion of Zone F varies with increasing distance from the airport boundary, the general trend is an increase. The 1,000-foot band closest to the airport has the lowest proportion of residential land at 15.7 percent, while the outermost 1,000 feet of the study area has the greatest proportion of the most noise-sensitive land at 42.5 percent, most of which is residential.

Hypothesis Two (Airport Boundary and Population Density)

The second hypothesis uses population density as an indirect way of assessing how land use changes with increasing distance from a general aviation airport. It states that population density increases with increasing distance from an airport boundary, up to a distance of one-half mile. The results of analysis support H_2 . The lowest population density (2,827 people per square mile) is found within 500 feet of the airport boundary, while the highest population density (9,709 people per square mile) exists in the

outermost 500 feet of the study area (Figure 16). From the airport boundary outward, population density increases at an average rate of 688 people per square mile for every 1,000 feet. The lower population density around the airport may be the combined result of zoning that discourages non-compatible uses, as well as the public's own reluctance to reside in the immediate airport area due to such perceived disamenities as noise, hazards, or an unpleasant view.

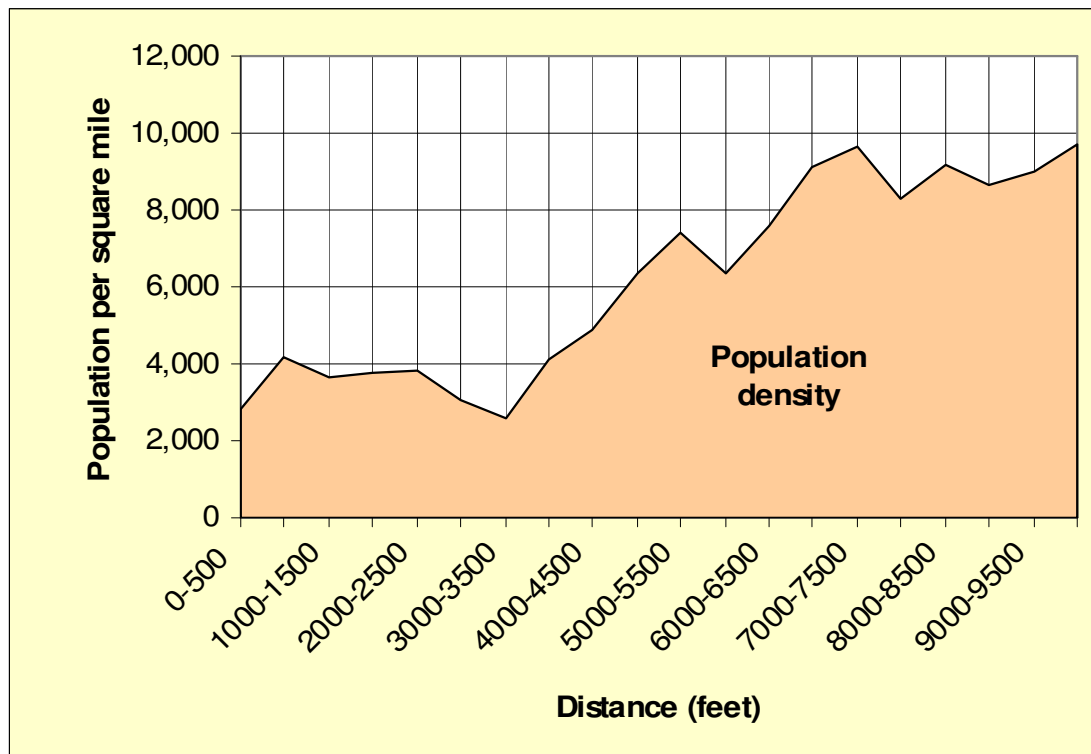


Figure 16. Population density as a function of distance from the airport boundary.

Research Question Two: Influence of Runway Orientation

Since noise, hazards, and pollution associated with operations of a busy airport are not distributed equally around the airport, it was presumed that the same principle that encouraged a spatial organization of land uses according to *distance* from the airport

boundary would also apply by *direction* from the airport. This would mean that certain sectors were more severely impacted by airport operations than others, and thus had a stronger tendency to exclude non-compatible (i.e. noise-sensitive) uses and attract compatible ones.

Hypothesis Three (Runway Orientation and Land Use)

While the first two hypotheses examine spatial patterns in terms of *distance* from the airport boundary, the second set of hypotheses examines spatial patterns in terms of *direction* from the airport, specifically, the extent to which runway orientation influences surrounding spatial patterns. The third hypothesis states that beyond the ends of the primary runway the proportion of the most noise-sensitive land uses (Zone F) was expected to be only ninety percent or less of what it was along the sides of the runways, and that this pattern holds true as far as one mile beyond either end of the runway. The analysis confirms this hypothesis. The proportion of Zone F land (residential, schools, and hotels) underlying the approach and departure sectors was nearly 15 percent less than those same land uses along the sides of the runway.

Aggregated Sectors. When the approach sectors were aggregated, they were found to have less noise-sensitive land (Zone F) than the aggregated side sectors. The approach sectors had only 24.1 percent Zone F, compared to 28.3 percent for side sectors, meaning the approaches had nearly 15 percent less¹⁸ Zone F land than the sides. This supports H₃. Conversely, the aggregated approach sectors also had a greater proportion of the least noise-sensitive land (Zone A: agriculture, water/floodplain, and transportation) relative to

¹⁸ $(28.27\% - 24.11\%) \div 28.27\% = 14.72\%$

the aggregated side sectors. The noisier and more hazardous approach sectors had 57.8 percent Zone A land, while the side sectors had 54.3 percent.

Individual Sectors. If the four sectors were looked at individually instead of being aggregated into sides and approaches, the results would be somewhat less supportive of the hypothesis (Table VI). While the south approach has at least ten percent less Zone F than either of the sides, the north approach fails to meet the ten percent requirement against the west side. In fact, this sector even has more Zone F land within it than the west. This can be explained by the fact that the land to the west of the airport is farthest from the Tulsa metropolitan area and is predominantly sparsely populated rural land, whereas the northern part of the study area is only four miles from downtown Tulsa. In summary, the research findings support the underlying assumption behind H_3 , that runway orientation does influence the location of land uses as a result of sensitivity to noise.

Zone F (residential, hotels, and schools)	
Sector	%
North approach	28.0
South approach	20.2
East side	33.8
West side	22.7

Table VI. Proportion of Zone F by individual sectors.

Hypothesis Four (Runway Orientation and Population Density)

As with the previous hypothesis, H_4 sought to reveal directional variation in land-use patterns around the airport as a function of runway orientation. Hypothesis four used

population density as an indirect means of measuring the affects of runway orientation on noise-sensitive residential areas (Zone F). This was the only one of the four hypotheses that could not be supported by the data. To accept H₄, the population density underlying the approach and departure paths of the primary runway would have to be at least ten percent less than densities at an equivalent distance in areas along either side of the runway, as far as one mile beyond the runway ends. When the approach/departure sectors were aggregated and the two sides were aggregated, the results were the opposite of what was stated in H₄. The combined approaches had a *higher* population density than the combined sides (Table VII). To accept H₄, the population density within the aggregated approach sectors would have to have been less than 1,596 people per square mile.¹⁹

Population Density (per square mile)	
Sector	Density
Approaches (aggregated)	2,430
Sides (aggregated)	1,773

Table VII. Population density by aggregated approach and side sectors.

When the four sectors are looked at individually rather than being aggregated into approach sectors versus side sectors, the results are no more supportive of the hypothesis (Table VIII). Only the population density in the south sector is more than ten percent below that on the east side. Otherwise, the individual approach sectors do not meet the requirements of the hypothesis.

¹⁹ $0.90(1,773) = 1,595.7$

Population Density (per square mile)	
Sector	Density
North approach	4241
South approach	620
East side	3066
West side	479

Table VIII. Population density by individual sectors.

Major Findings

1. Approximate Range of the Airport's Influence

Following Haywood's (1999) evaluation of the impact of trams (light rail) on land use, land use in this study was found to respond to the presence of a general aviation airport. Likewise, the effect of distance decay found by Haywood is evident around the airport, since the effect of the airport on nearby land uses weakens with increasing distance. The 400-meter limit Haywood used for his study area, which is equivalent to 1,312 feet or about one-fourth of a mile, may have been an appropriate range of influence for a tram route since it was restricted. However, the less constrained nature of aircraft operations is such that aviation impacts are not restricted to specific paths, thereby necessitating a broader study area. Similarly, Minton (2006) refers to the effect of the Houston convention center on the transformation of the city's downtown, with landscape-changing results evident within a mile of the convention center. Finally, Gumprecht (2003) does not provide a specific distance for the impact of colleges beyond their property lines, but indicates adjacent land uses are affected.

Based on the findings, the range of the airport's influence over most surrounding land

uses is approximately 2,000 feet. It should be noted that this distance is less than what had been anticipated. By evaluating land use and population density, it appears that 2,000 feet is a natural breakpoint at which the proportions of several land-use types undergo significant change (Figures 17 and 18). That range marks a transition area beyond which noise and other undesirable aspects of airport operations are no longer significant factors hindering residential development. Beyond 2,000 feet the impacts of airport operations at this busy GA airport appear to be negligible and other factors influencing land use become more important. At a busy commercial service airport used by large, multi-engine jet transports, the effect would be even farther out.

The key to understanding the effect of the airport on Zone F (residential, schools, and hotels) is on the area between the airport and the 2,000-foot distance at which residential proportions peak (Figure 17). From a low of 13.8 percent along the airport boundary, the proportion of Zone F land use nearly triples to a peak of 39.4 percent at 2,000 feet. This suggests that the presence of the airport discourages Zone F land uses from locating nearby, but this influence tapers off with distance, reaching its limit at 2,000 feet. Southeast of the airport, just on the other side of 91st Street, is a subdivision containing houses having the closest proximity to the airport. This is the Melody Lane subdivision, with houses built in the 1970s, well after the airport was established.

Between the population concentrations in Jenks and Tulsa, the proportion of residential land declines, but rises again and reaches its highest value at the outer limit of the study area because of proximity to the city of Tulsa (Figure 18). This is consistent with Espey and Lopez (2000), who found that noise from commercial jet traffic negatively affected nearby residential properties within at least one mile from the airport,

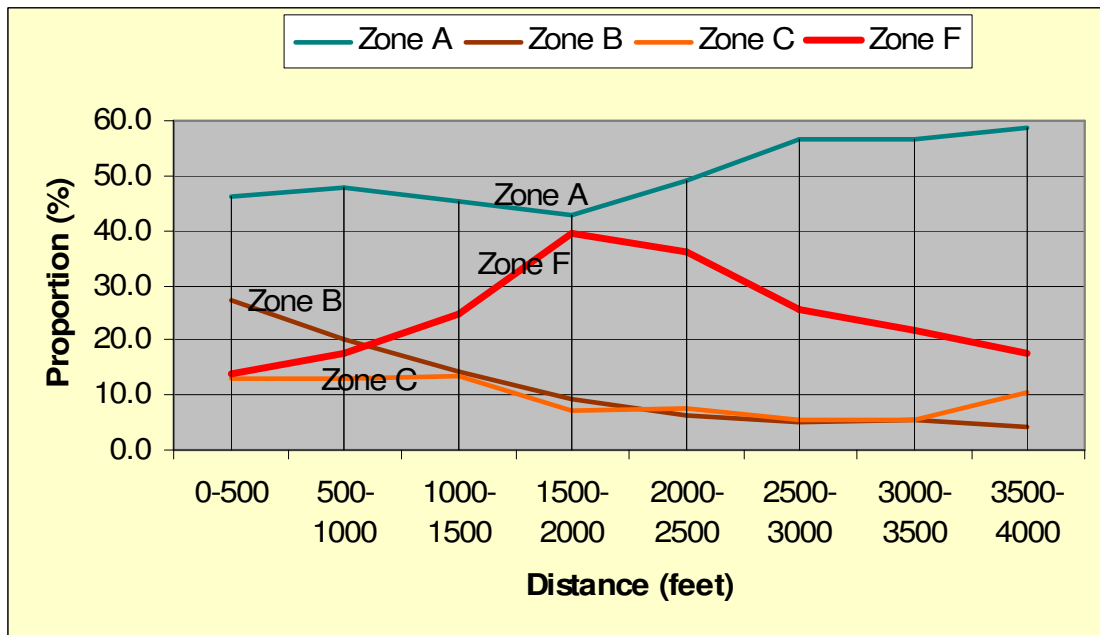


Figure 17. Land-use zone proportions by distance.

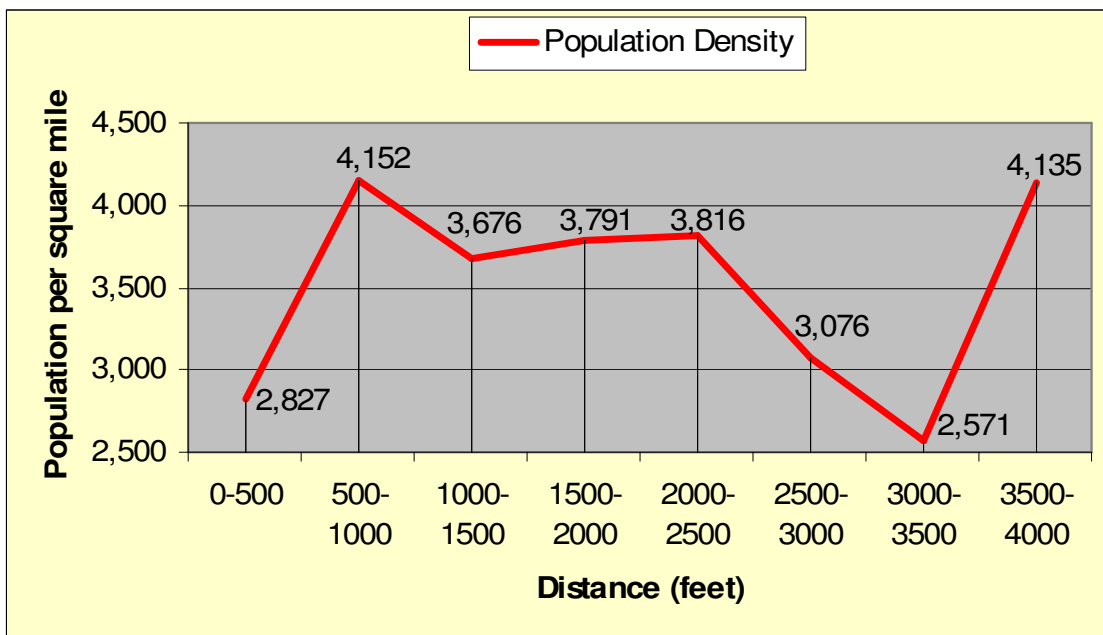


Figure 18. Population density by distance.

resulting in fewer dwellings. The results from this study suggest that the same principle applies at a general aviation airport with smaller, mostly propeller-driven aircraft. However, as indicated previously, the 2,000-foot influence of this GA airport is considerably smaller than that of a commercial service airport with its undesirable impact from frequent and noisy transport jets.

In H₂, population density was used as an indirect indicator of residential land, which is by far the largest component of Zone F. The distance of 1,000 feet from the airport boundary is significant for population density. At that range, the average population density peaks at 4,152 persons per square mile and remains near that level extending outward to the edge of Jenks. This apparent breakpoint for population is closer to the airport than for residential land. Nonetheless, since land use is the focus of this study and population density follows residential land, 2,000 feet was identified as the distance at which the airport's influence over noise-sensitive land uses begins to taper off.

It is also at 2,000 feet that the proportion of Zone A (agriculture, water and floodplain, and transportation) reaches its lowest value at 42.7 percent. At the airport boundary the proportion of Zone B (industry and utilities) is at its highest, reaching 27.3 percent. The general trend is that less industrial land is found at greater distances from the airport. At 2,000 feet out, the proportion of industrial land drops to 9.3 percent, nearly one-third of what it is at the airport boundary. Beyond that distance the rate of decline begins to slow.

Likewise, it is at 2,000 feet that the proportion of Zone C (consisting mainly of South Lakes Golf Course, stores, and offices) abruptly drops to nearly half of what it is near the airport, from an average of 13.1 to just 7.1 percent. The proportions of Zones D and E are insignificant. Zone D (parks, hospitals, and churches) remains low out to 2,500 feet,

averaging only 1.2 percent, while the only case of Zone E (nature exhibit) is the Oklahoma Aquarium in Jenks, which is located over 6,000 feet from the airport.

2. No Simple Gradation of Land Uses

Another major finding was that most of the land use zones did not follow expected patterns. If sensitivity to airport noise were the only factor affecting land-use decisions in the vicinity, land use would be represented by an orderly, predictable gradation of land-use zone proportions outward from the airport boundary (Table IX). Zone A, being the least sensitive to noise, would have the largest share of land area close to the airport boundary. This would transition to predominantly Zone B farther away, then Zone C, and so on until reaching the edge of the study area, where Zone F (residential) would be the principal land use. Such clear differentiation was not the case (Figures 15 and 19). According to the same rationale, we would expect the most noise-sensitive land uses to avoid locations close to the runway ends where aircraft are taking off and landing. Here too, the research results do not indicate a clear pattern in terms of directionality of land use.

One possible explanation of these muddled land use patterns is that certain land uses group together by function or similarity, and not just by gradation of noise sensitivity. As already mentioned, industrial land uses (Zone B) are highly concentrated around the airport. It is difficult to say that this is only due to their greater tolerance of airport noise. Perhaps it has as much to do with segregating unsightly land uses away from other uses. Another factor to consider is the possibility of functionally compatible uses grouping together. Ryan (2005) found that some industrial firms (Zone B) and office properties

Land-use Zones					
A	B	C	D	E	F
Agriculture	Industry and utilities	Offices and stores	Hospitals	Nature exhibits and zoos	Residential
Water and floodplain		Government services	Churches		Hotels and lodgings
Transportation		Golf courses	Parks		Schools

Table IX. The six land-use zones created for this study (ordered from A to F according to increasing noise sensitivity).

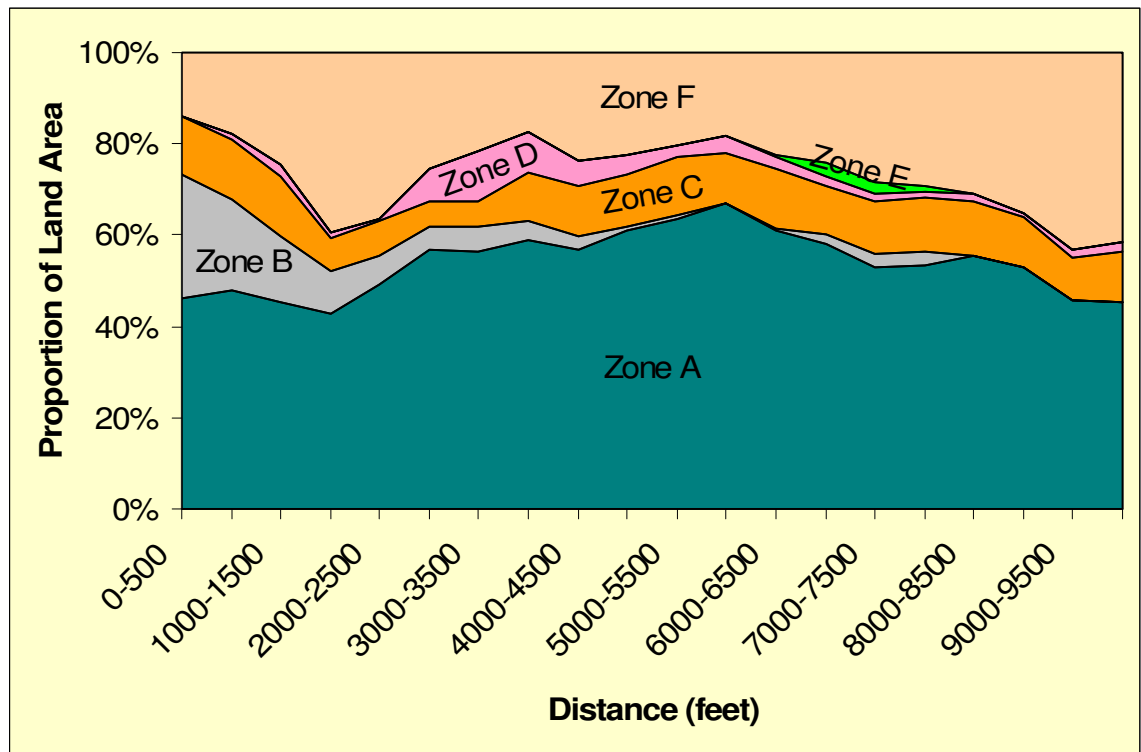


Figure 19. Proportions of the six land-use zones throughout all twenty buffers (from airport boundary to 10,000 feet)

(Zone C) valued proximity to similar land uses. The result was a clustering of similar economic activities, a phenomenon known as agglomeration.

We should also be reminded that the airport is not the only major landscape feature influencing land use, as if it were the focal point of Tulsa or Jenks. While airports can be initiators of land-use change, there are other factors contributing to spatial patterns (Adedibu 1977). Airports function as just one of many nodes or focal points in urban areas, such as city cores and major shopping districts (Harris and Ullman 1945).

3. Preponderance of Agricultural and Residential Land Uses

An unexpected finding was the extent to which Zone A and Zone F land uses dominated other land-use types throughout the study area. In particular, the amount of agricultural and residential land was significantly higher than any other land use. Prior to conducting the analysis, the expectation was that the proportions of the land use zones in the entire study area would be distributed relatively evenly, with each type covering about one-sixth of the land area. However, when combined, land-use zones A and F comprise 80.8 percent of all land uses in the study area used for research question one. Agriculture alone accounts for 34.5 percent of all land, reaching as high as 41.6 percent at a distance of 6,000-6,500 feet from the airport boundary. Residential land accounts for 24.4 percent. The remaining 19.2 percent of land is divided among the other four land uses. When looking at land use from the directional perspective (H_3), Zone A also comprises the largest portion for each sector. Zone F is second.

There is also an inverse relationship between Zone A and Zone F. As the amount of residential land increases, agricultural land decreases, and vice versa. From 1,500 feet to

10,000 feet, their combined land use generally varies only by seven percent (82 to 89 percent) (Figure 20). However, their combined percentage begins a steady decline from 2,000 feet in the direction of the airport boundary as the amount of industrial land increases. This suggests that the expected predominance of agricultural and residential land that one normally finds on the landscape declines with proximity to the airport and may be attributable to the operations of the airport.

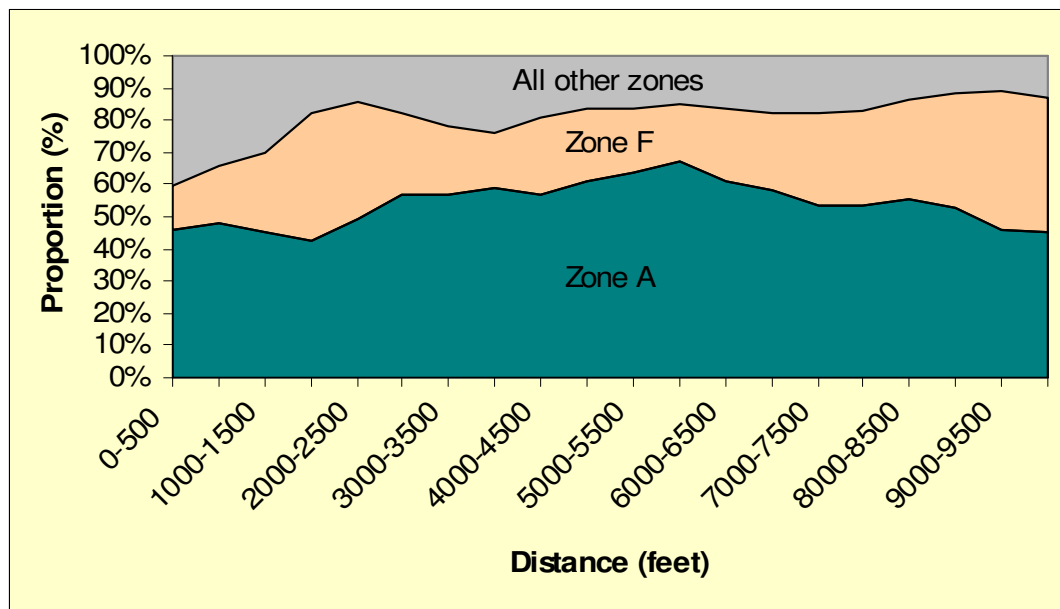


Figure 20. Combined proportions of Zone A (agriculture, water, and transportation) and Zone F (residential, hotels, and schools).

4. Association of Zone B (Industry and Utilities) with the Airport

Another finding was the close association between the airport and industrial-type land uses (Zone B). In fact, Zone B land use is in greatest proportion within 500 feet of the airport boundary where they comprise 27.3 percent of all land uses (Figures 21 and 22). The proportion of Zone B tapers off as one moves away from the airport until reaching 4,500 feet. Beyond this distance, it is almost nonexistent. As the amount of industrial land

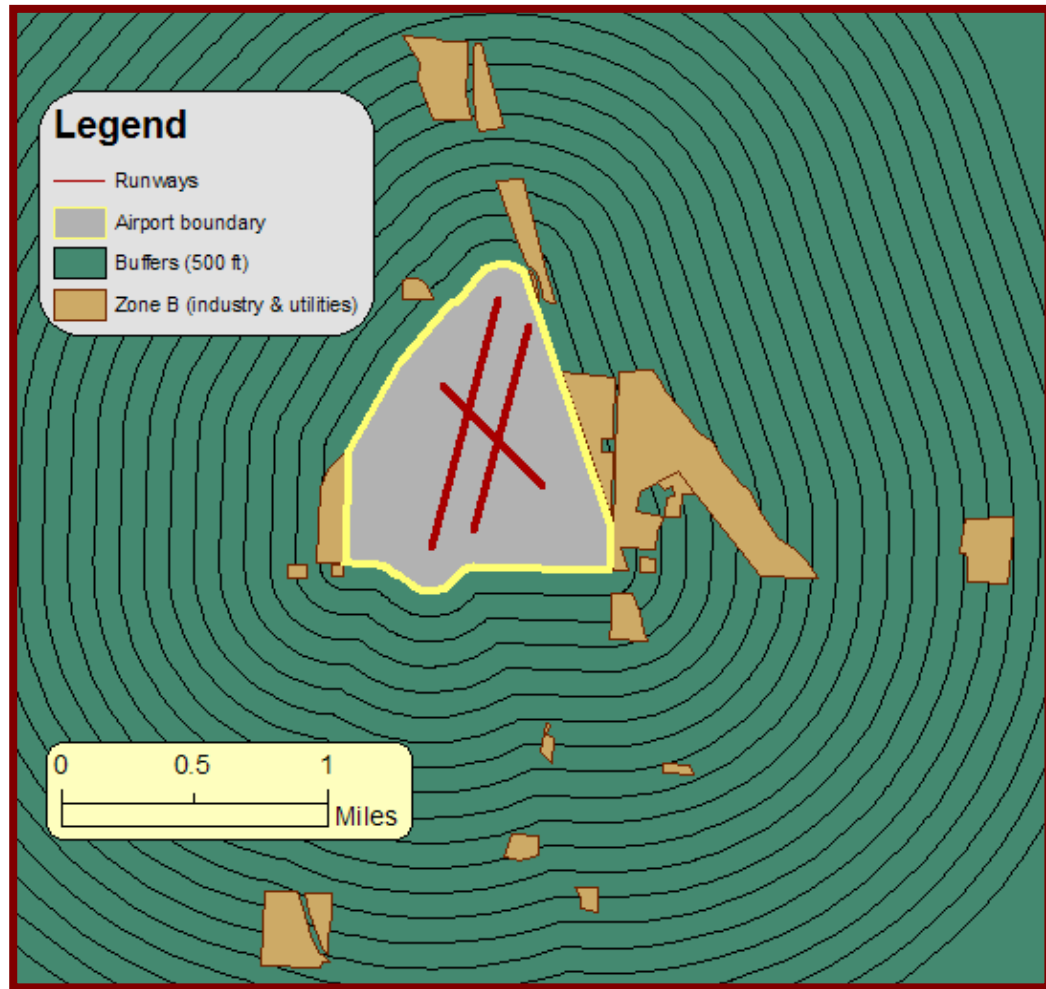


Figure 21. Zone B land use (industry and utilities).

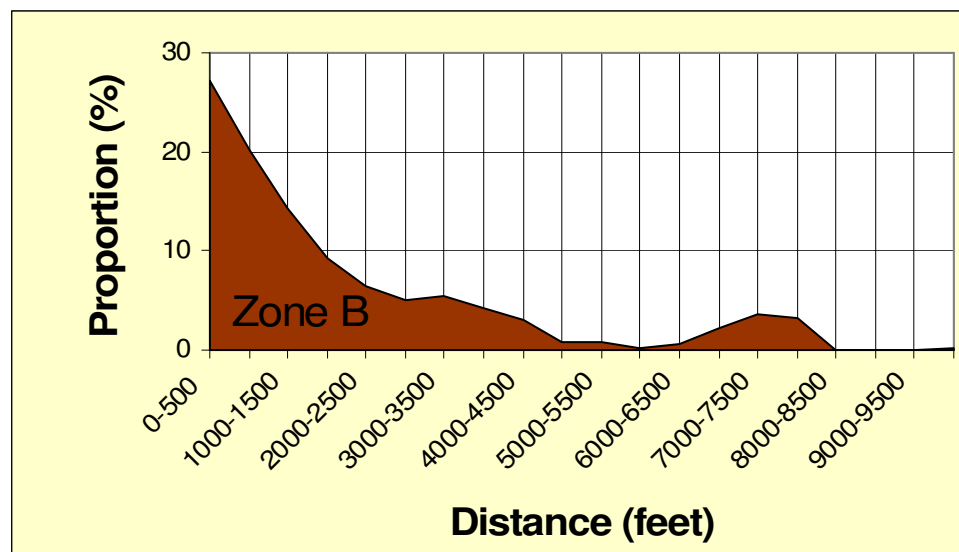


Figure 22. Proportion of Zone B as a function of distance.

decreases away from the airport, the amount of residential land rises proportionally. Between the east side of the airport and the Arkansas River are some industrial parks. Figure 4 shows one of those industrial properties, a business within the Jenks city limits operated by Liberty Precast LLC, located at the northeast corner of South Peoria Avenue and North Birch Street. Although McLemore (1988) indicated that airport operators sometimes seek to be affiliated with an industrial park, a survey of the area did not provide evidence that this was the case. There was no apparent linkage between these businesses and airport activities. Even without a direct relationship, this may be an example of similar or complementary uses being drawn together (Ryan 2005). If so, this would be a contributing factor explaining the spatial pattern of Zone B land use close to the airport, and would indicate that influences are at work besides the graduated noise scale and other disamenities. Having these industrial parks adjacent to the airport also serves to protect it from encroachment arising from less compatible land uses (McLemore 1988).

5. The Even Distribution of Zone C by Distance

Most of Zone C consists of commercial-type properties such as offices, stores, and government services. It also includes golf courses. The results indicate that the distribution of Zone C land has little variation with distance. It has the most consistent proportion of any of the land-use zones, except for a slight reduction between 1,500 and 3,500 feet (Figures 15 and 17). Zones B, D, and E all have one or more buffers in which the category of land use does not exist, whereas Zone C never dips below 5.5 percent in any buffer, averaging 10.4 percent throughout all the buffers. However, by sector, it is

not the most consistent. Zones B and D have smaller extremes. Nonetheless, with twenty buffers versus only four sectors, the consistency with distance is considered more significant.

Within 2,000 feet of the airport, most Zone C land is attributable to South Lakes Golf Course, located south of the airport on the other side of 91st Street. Less than 40 percent comes from commercial-type properties, such as offices, retail stores, and government services. Beyond 2,000 feet, commercial properties overtake golf course land as the bulk of Zone C for the remainder of the distance. At the same time, commercial properties never occupy more than three percent of all land within the first 2,000 feet, but beyond that distance, their proportion among all land-use types rises. These patterns provide evidence that Jones Airport has had some impact on commercial properties. By doing so, it not only supports Adedibu's (1977) findings regarding commercial land use changes around Jacksonville International Airport, but it also helps to reveal the range of the airport's influence.

Another trend is the association between Zone F (primarily residential) and Zone C (primarily commercial). As the proportion of residential land use increases, the proportion of commercial properties and government services also rises accordingly. The proportion of Zone C land averages 38.5 percent of whatever Zone F's proportion is.

6. Unclear Results Regarding Directional Influence

Determining the range of the airport's influence was one goal of this study. However, a second objective was determining directional variation in the influence of airport operations. Although the third hypothesis was validated with regard to residential land,

the overall research findings were not definitive. For example, it is not clear that noise-sensitive land uses avoid approach sectors. Table X indicates the proportion of each land-use zone within each sector. With reference to research question two, Zone A (primarily agriculture) dominates all sectors, followed by Zone F (primarily residential). However, variations in the proportions of all the land-use zones appear to have little association with this sector. Insufficient data makes it difficult to generalize about Zone E (nature exhibits). There is only one occurrence of this land-use type, located in the east side sector.

Sector		Land-use Zone					
		A	B	C	D	E	F
Approaches	North Approach	51.7%	4.0%	9.6%	6.7%	0.0%	28.0%
	South Approach	64.0%	2.9%	9.0%	3.9%	0.0%	20.2%
Sides	East Side	39.8%	6.7%	14.4%	3.9%	1.4%	33.8%
	West Side	68.9%	0.9%	7.4%	0.2%	0.0%	22.7%

Table X. Proportion of each land-use zone by sector.

In evaluating land uses and the population densities by sector, it appears that the sectors are strongly influenced by the airport's geographic situation relative to population concentrations within the Tulsa metropolitan area (Figures 23 and 24). Jones Airport is situated on the edge of a large urban area concentrated to the northeast of the airport. Except for the area around the city of Jenks, the sections south and west of the airport are largely rural and have low population densities. Accordingly, agricultural land (Zone A) is most abundant to the west and south, away from the urbanized area (Figure 23). In

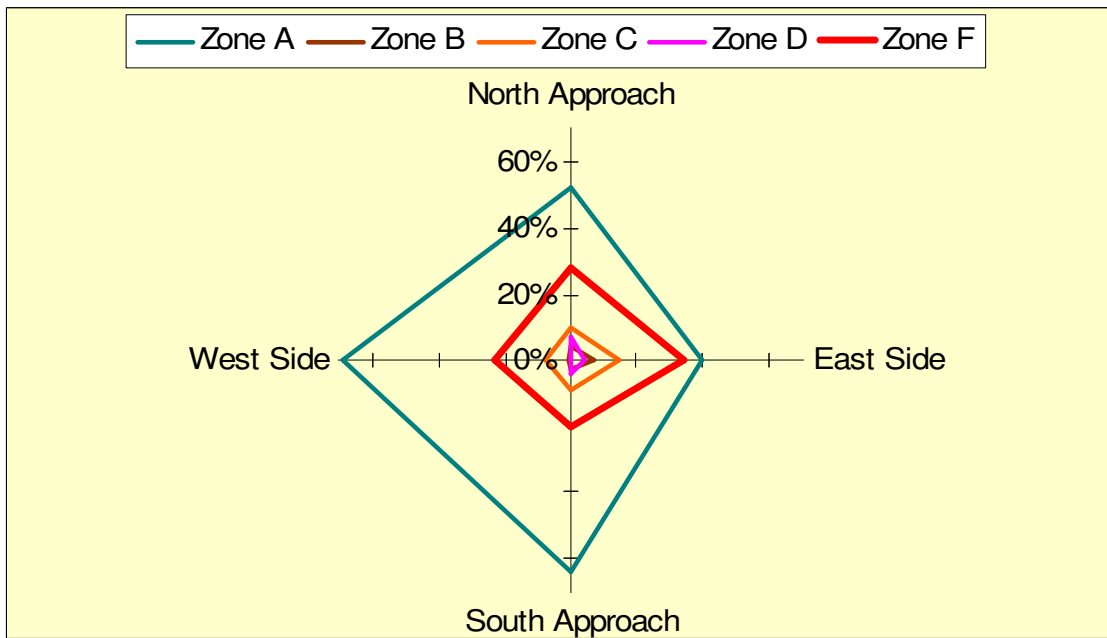


Figure 23. Land-use zone proportions by sector.

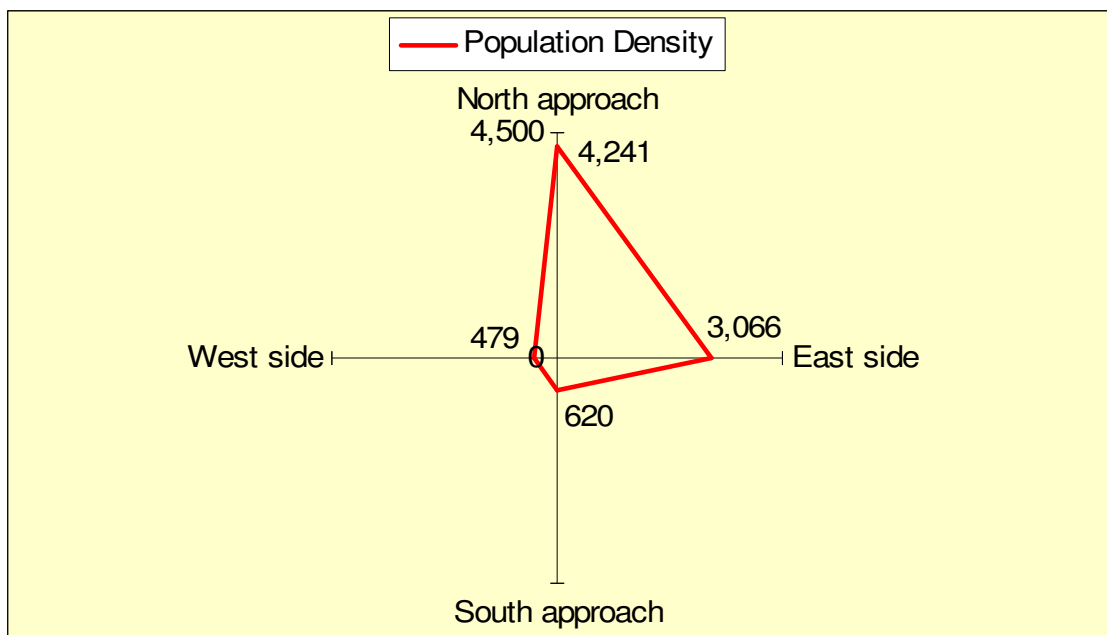


Figure 24. Population density by sector.

contrast, land uses other than agricultural are pulled towards the more urbanized sections of the study area having the highest population densities. Residential areas and schools (Zone F) predominate to the east and north, toward this urban concentration. The other four land-use zones are relatively insignificant, but even they exhibit a tendency towards the urbanized east and north. Population patterns are similar to the land-use patterns. The results from H_2 indicate that population density increases with greater distance from the airport, while the results from H_4 indicate that population is concentrated to the north and east of the airport. Figure 24 depicts the population density for each of the four sectors and connects the vertices to provide an abstract portrayal of population concentration within the study area.

Although this might suggest that the assumptions regarding the influence of runway orientation were incorrect, one must bear in mind that each of these sectors extends 10,000 feet beyond the primary sector, well beyond any airport influence. Were the outer limits of the four sectors drawn closer to the primary sector, perhaps 4,000 feet, the results might have been more supportive of the initial assumption. The distance of 4,000 feet is an estimate based on the 2,000 feet identified in the previous section, plus an additional 2,000 feet stemming from the assumption that land uses are pushed farther out beyond runway ends. It also attempts to factor in a sufficient margin for ensuring that all effected areas are included for consideration.

CHAPTER 7

CONCLUSION

Overview

This final chapter synthesizes the results of the study. It begins by comparing the research results to similar studies. Then, the usefulness of the methodology and research findings for other studies is considered, including the implications of the findings and how they contribute to the discussion of airports and land use. Finally, it offers some suggestions for future studies and closes with some final remarks.

Conclusion

Comparison to Other Research

This study draws on von Thünen's agricultural land-use model and models of urban spatial structure to show how land is spatially organized in a recognizable, and even predictable, pattern around a central feature. In von Thünen's model, the central area was the market center and the surrounding land was organized spatially into concentric rings with each ring representing a particular agricultural product largely as a function of the cost to transport goods to market (Hall 1966). This study was loosely based on these concepts by applying them to disamenities associated with airports, such as noise. However, instead of looking at an entire city, this study focused on an area within 10,000

feet of an airport, with rings based on six categories of land use that were sorted by noise sensitivity.

Hoyt's (1939) model of urban spatial structure describes sectors radiating outward from the central business district (CBD), with parts of the city associated with specific kinds of land uses or activities in the city's development. As the city expands, these same land uses and activities tend to radiate outward from their original areas, resulting in a sector-shaped area characterized by the predominance of that land use or activity. Likewise, this study used the sector concept to analyze the directionality of land use and population density in H_3 and H_4 . The four sectors were also based on land use (or population density), but were used to distinguish areas according to their noise sensitivity.

The patterns of modern urban structure are actually more complex than either of the preceding models would suggest. In reality, the multiple nuclei model (Harris and Ullman 1945) may more accurately reflect the spatial structure of a modern urban area. Similarly, after having analyzed the area around Jones Airport in terms of both distance (buffers) and direction (sectors), the configuration of land use was found to be more complex than can be explained by either model applied separately.

Usefulness of the Methodology

This section discusses the usefulness of the methodology employed in this research. The procedures used for analyzing land use and population patterns around a general aviation airport could be applied to analyzing spatial patterns around other general aviation airports, as well as commercial service airports and military airfields. While the

methodology can be useful for all kinds of airports, it is certainly not limited to airports. It could potentially be used for studying areas around other major transportation facilities, such as interstate highways or ports. For that matter, any large construction project having the potential to influence land use and population patterns around them would be a suitable entity for study using the approach outlined here. This could include shopping malls, stadiums, amusement parks, factories, and so on. The advantage of using a geographic information system is its ability to produce customized maps that may be manipulated as needed and its spatial analysis capability. The techniques are also generalizable for other projects, even though the results of the study may not be.

The results are also useful as a baseline for guiding similar research. While a case study approach was used for this study, studies of other airports may add to the body of knowledge, and may help to uncover common patterns of land use or population around similar airports. Furthermore, since similar factors influencing land use around GA airports (noise, etc.) exist at commercial service airports, many of the findings will have application to these types of airports as well. This is said with recognition that some differences exist between the two types of airports. In contrast to a general aviation airport, a commercial service airport serves primarily large and loud turbine-powered airplanes with greater performance capabilities and more demanding requirements. These airplanes also fly different flight paths and profiles, in different kinds of operations, and with different frequencies of operation. Commercial service airports must be equipped to accommodate thousands of passengers and visitors a day, and are likely to attract more airport-related businesses, such as air cargo, car rental agencies, hotels and motels, restaurants, and parking.

Suggestions for Future Research

Two recommendations for future studies are suggested. One involves redefining the land-use zones created for this study, while the other seeks to determine contributing causes that give rise to observed spatial patterns. Future studies using a similar land-use scheme may want to consider breaking this up into two or more separate zones that would distinguish among agriculture, water and floodplain, and transportation. Doing so would also help to reduce the large gap in proportions between Zone A and the other five zones. Secondly, there remains some uncertainty as to catalysts behind the spatial patterns of land use around the airport and the degree to which each is responsible for exerting influence. Future studies, perhaps incorporating statistical tools, could attempt to isolate causal factors to provide a better understanding of the cause and effect behind spatial patterns.

At least four possible contributing factors to spatial patterns around airports have already been discussed. These were the affects of noise, safety concerns, environmental impacts, and economics. In addition to these four, other factors may include the dynamics of the local real estate market and the trajectory of urban development, as well as community perceptions and attitudes. There are also indirect factors that may influence spatial patterns of land use. Among these are government regulations and policies, such as local zoning ordinances, federal and state regulations, and even an airport's own policies, such as operational curfews and noise abatement procedures. The operational characteristics of the aircraft and their flight profiles are another factor that could influence spatial patterns. Furthermore, operational factors can affect an airport's footprint on the landscape (Horonjeff and McKelvey 1994). Relevant operational

characteristics having the potential to affect the landscape include runway lengths and layout, the amount of use for each runway, the number of aircraft operations by aircraft type and the day/night split of those operations, and flight paths (Horonjeff and McKelvey 1994). Other factors may include the types of operations at an airport (touch-and-go's, practice approaches, etc.), traffic pattern procedures, and the geographic setting (terrain, climate, etc.).

Final Remarks

Three of the four hypotheses were supported by the results of this study, which showed that a general aviation airport does indeed have an impact beyond its boundary due to the presence of the airport itself, as well as the runway orientation. However, distance was shown to be more decisive than directionality. One of the major findings was that the range of this airport's influence was about 2,000 feet. However, the directional preferences of that influence are not clear, perhaps due to the way in which the research parameters were established. Also, the land-use pattern did not reveal an orderly transition of land-use types according to distance, as was expected. Other significant findings were the location of industrial properties close to the airport, the high percentage of agricultural land and residential properties, and the fairly even spatial distribution of commercial properties.

The goal of this study was to expand the body of knowledge pertaining to land use and general aviation airports. While researchers have discussed issues related to land use in the vicinity of large commercial service airports in Denver (Carlsen 2002), Reno (Espey and Lopez 2000), Milwaukee (McAdams 1995), Jacksonville (Adedibu 1977), and other

cities, this is the first to evaluate land use around a general aviation airport. The evidence supports findings from previous studies suggesting that the presence of an airport with a large number of operations does result in changes to land use within adjacent areas (Sealy 1968; Adedibu 1977; Bright 1980; Carlsen 2002). The results lend support to the idea that airports can be initiators of land-use change (Adedibu 1977) and provide insights into patterns that emerge in response to land-use compatibility issues involving airports (Bright 1980). What is not certain is the degree to which each of several possible factors (noise, safety concerns, environmental degradation, economics, and visual intrusion) has contributed to the airport's influence on nearby land use and whether these factors are consistent for other general aviation airports in the United States.

One of the most significant implications of this study is that it represents among the first attempts to delimit distance and directional patterns of land use around an airport. While others have acknowledged the influence of airports on nearby land use, or implied that it exists, none have attempted to quantify it (Griffith 1955; Adedibu 1977; McLemore 1988; McAdams 1995; Carlsen 2002; Cidell 2003b). The results here may be useful as a guide for estimating appropriate dimensions for future study areas, and may serve land developers and airport operators with information to help them make better policy decisions.

By focusing on general aviation airports, it is hoped that this study will encourage others to examine airports and land-use issues tied to aviation. Many of the themes explored in transport aviation, such as traffic flows, economic impacts, and environmental implications, are also relevant to general aviation (Hoyle and Knowles 1998). Increasing our knowledge of the spatial aspects of general aviation will give us a

more complete picture of civil aviation in terms of its role and impacts on society.

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**APPENDIX A – NUMBER OF AIRPORTS IN
THE UNITED STATES BY TYPE (2006)**

Total Airports	19,983
Airports Open to the Public (Public Use Airports)	5,233
General Aviation Airports	4,629
Certificated Airports ²	604
Airports Closed to the Public (Private Use Airports)	14,750
Abandoned Public Use Airports	27
Abandoned Private Use Airports	133
¹ Includes civil and joint-use civil-military airports, heliports, STOLports, and seaplane bases in the U.S. and its territories. ² Certificated airports serve Air Carrier Operations with aircraft seating more than nine passenger seats (FAR Part 139). Most of these airports also serve general aviation.	

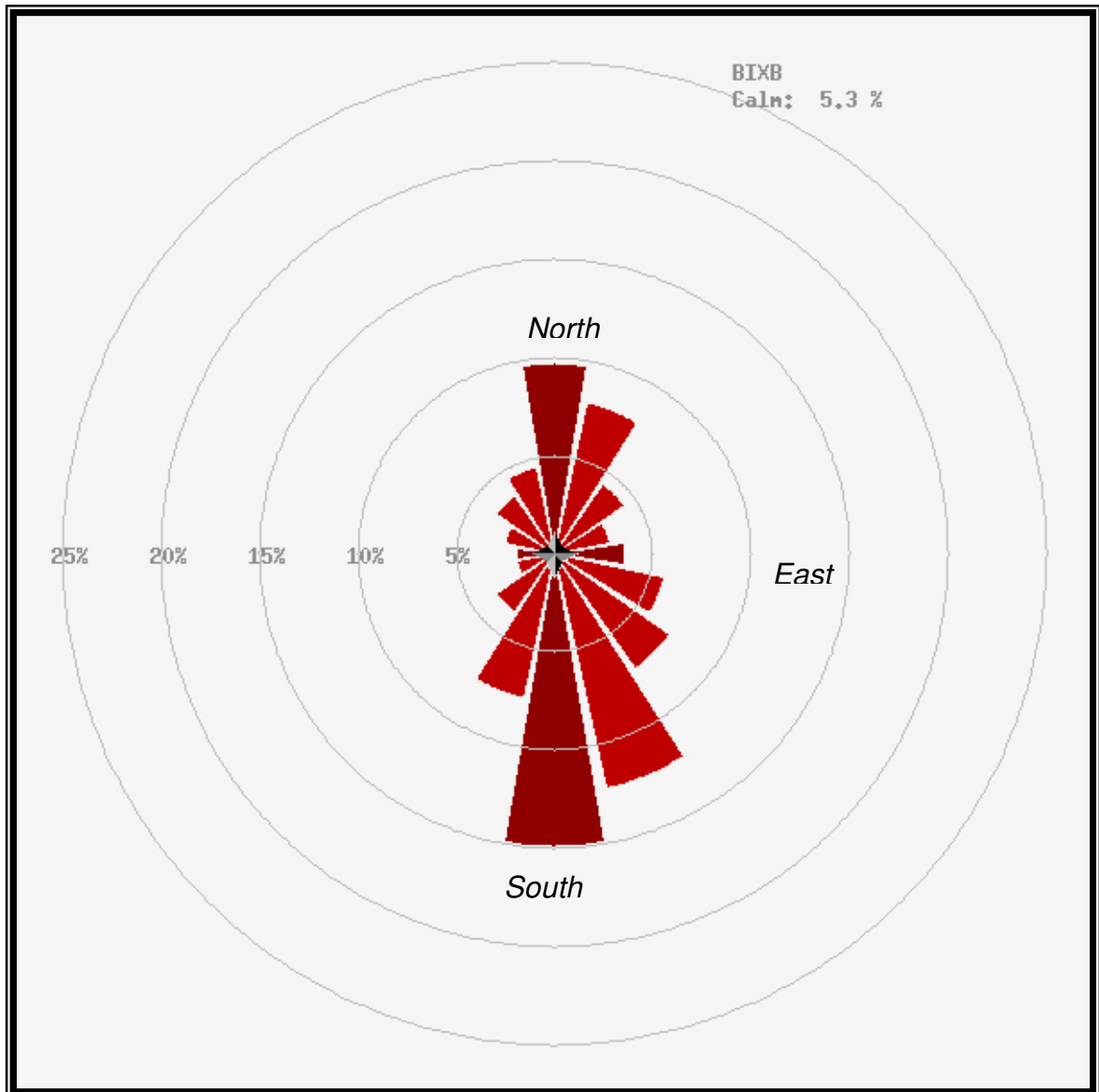
Source: Administrator's Fact Book (FAA, April 2007)

**APPENDIX B – GENERAL AVIATION AND AIR TAXI
ACTIVITY IN THE UNITED STATES (2005)**

U.S. General Aviation and Air Taxi Activity (2005)		
	Estimated Active Aircraft (thousands)	Estimated Hours Flown (millions)
Total	224.4	27.0
By type of Aircraft		
Piston	167.6	16.4
Turboprop	7.9	2.1
Jet	9.8	3.8
Rotary Wing	8.7	3.1
Experimental (incl. amateur built)	23.6	1.3
Light Sport	0.2	0.0
Others	6.5	0.3
By type of Flying		
Personal	151.4	9.3
Instructional	13.4	3.6
Business	25.5	3.2
Corporate	10.6	3.1
Air Taxi	6.9	2.9
Aerial Observation	4.7	1.3
Aerial Application	3.5	1.0
Aerial Other	0.8	0.1
Air Medical Services	1.4	0.7
Air Tours	0.6	0.4
Sightseeing	0.9	0.2
Other Work	0.9	0.3

Source: Administrator's Fact Book (FAA, April 2007)

APPENDIX C – WIND ROSE FOR BIXBY MESONET SITE (1994-2001)



Source: Oklahoma Climatological Survey (OCS 2007)

The Bixby Mesonet site is located nine miles southeast of Richard Lloyd Jones Jr. Airport. The data from this site was selected because it was readily available and it could be compared with other environmental monitoring stations within the Oklahoma Mesonet. Wind roses are important to airports because they indicate the direction and strength of prevailing winds.

APPENDIX D – FOUR SELECTED RUNWAY ELEMENTS RELEVANT TO OBJECT CLEARING CRITERIA

1. Runway Object Free Area (OFA). This is a rectangular ground area centered on the runway “centerline provided to enhance the safety of aircraft operations by having the area free of objects” (FAA 2007b, 2). For the largest runway at Jones Airport (1L/19R), which has an airport reference code of B-II, the runway OFA extends 300 feet beyond each end of the runway and is 500 feet wide (FAA 2007b).

2. Runway Safety Area (RSA). This is another rectangular surface area surrounding the runway and centered along its centerline, but which has been prepared for or is suitable for reducing the risk of damage to an airplane in the event that it misses or departs the runway surface (FAA 2007b). The RSA for runway 1L/19R extends 300 feet beyond each runway end and is 150 feet wide (FAA 2007b).

3. Runway Obstacle Free Zone (ROFZ). The runway OFZ is a volume of airspace shaped like a rectangular prism and centered along the runway centerline from the surface up to 150 feet (45 m) above the established airport elevation. This three-dimensional area is established to provide clearance protection for aircraft landing on, taking off from, or overflying the runway (FAA 2007b). The runway OFZ extends 200 feet beyond each runway end. The width depends on the size of the airplanes intended to use the runway and on the approach visibility minimums. For runways usable by large airplanes (those over 12,500 pounds), ROFZ is 400 feet wide (i.e. 200 feet either side of the extended runway centerline).

This and the previous two areas are similar to each other in that they are rectangular areas surrounding the runway. In that regard, all three are also similar to the primary surface discussed in FAR 77, but the runway obstacle free zone is most reminiscent of it. These three rectangular surfaces from AC 150/5300-13, “Airport Design,” were considered for use in this research, but in the end, the primary surface was the preferred reference for the runway area, and even then, it was used only for exploring hypotheses three and four. It was selected because of its integration with other surfaces from FAR 77 and because of its dimensions.

4. Runway Protection Zone (RPZ). This is a trapezoidal-shaped area beyond each end of the runway and centered about the extended runway centerline. It is similar to the approach surface discussed in FAR 77. RPZs are established “to enhance the protection of people and property on the ground” (FAA 2007b, 2). The RPZ dimensions “for a particular runway end is a function of the type of aircraft and approach visibility minimum associated with that runway end” (FAA 2007b, 13).

Generally, “the RPZ begins 200 feet (60 m) beyond the end of the area usable for takeoff or landing” (FAA 2007b, 13). Because runway 1L at Jones Airport has an instrument approach with a visibility minimum of $\frac{3}{4}$ mile, the runway protection zone at the approach end is 1,700 feet long. The inner width of this RPZ is 1,000 feet and the outer width is 1,510 feet. Since all other runways at Jones Airport either have instrument approaches with higher visibility minimums or are limited to visual approaches only,

their RPZ dimensions are smaller.

The FAA specifies several land-use criteria that apply within an RPZ. “While it is desirable to clear all objects from the RPZ, some uses are permitted, provided they do not attract wildlife,...are outside of the Runway OFA, and do not interfere with navigational aids” (FAA 2007b, 13). For example, although automobile parking facilities anywhere in the RPZ are discouraged, they may be permitted in those areas that are at least 250 feet (in the case of ARC B-II) away from the extended runway centerline.

Certain other land uses are prohibited from the RPZ. Prohibited uses would include residential areas and places of public assembly, such as places of worship, “schools, hospitals, office buildings, shopping centers, and other uses with similar concentrations of persons.... Fuel storage facilities should not be located in the RPZ” (FAA 2007b, 13).

In cases where the airport operator is not able “to acquire and plan the land uses within the entire RPZ, the RPZ land use standards have recommendation status for that portion of the RPZ not controlled by the airport owner” (FAA 2007b, 13).

Source: FAA Advisory Circular 150/5300-13, “Airport Design”

APPENDIX E – SEVEN SURFACE AREAS+ CONSIDERED FOR GUIDANCE IN TESTING H₃ AND H₄

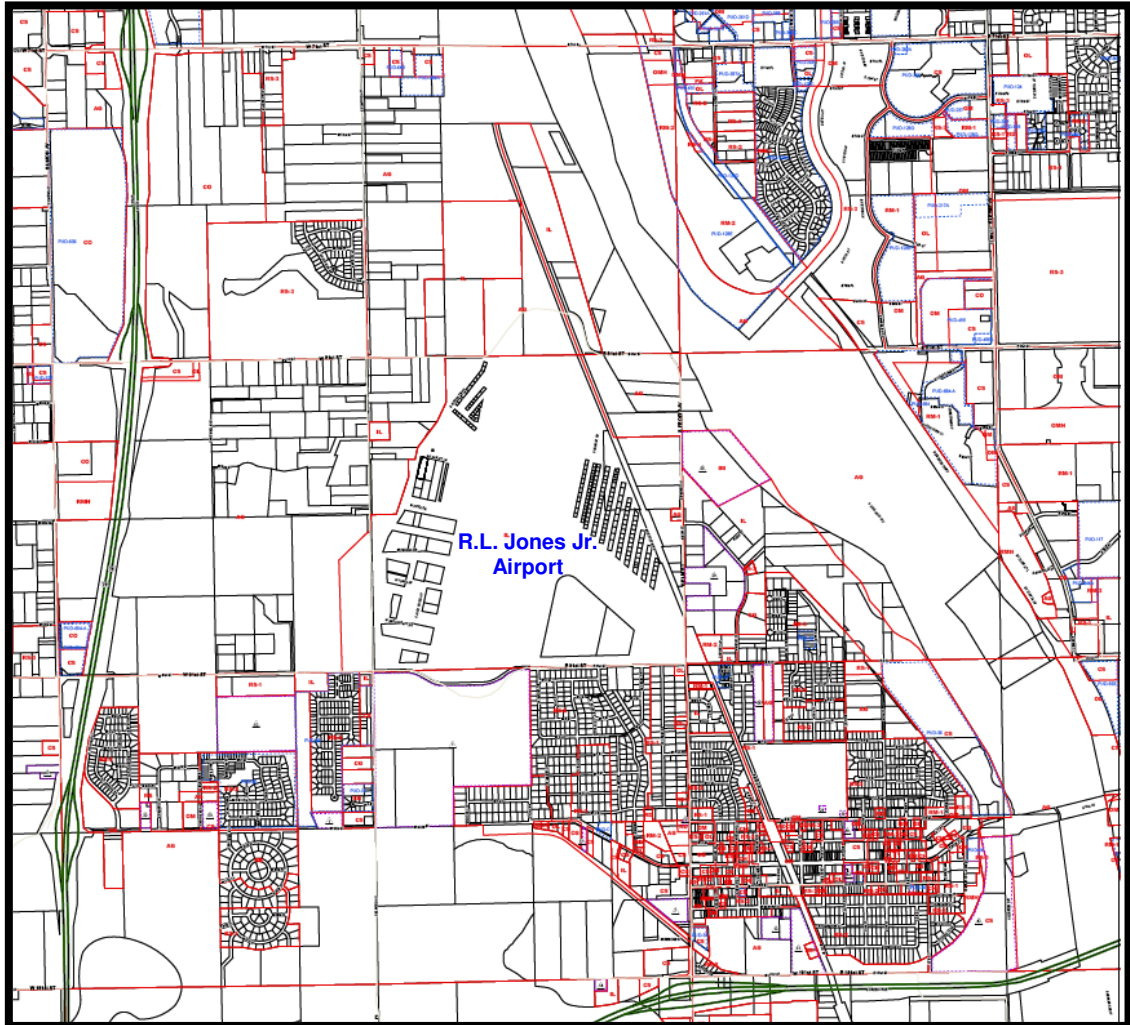
Zone/Area/Surface	Source	References	Comments
Runway Object Free Area (ROFA)	AC 150/5300-13, "Airport Design"	¶ 2, 201, 211, 212; 307; Fig. 2-3; Table 3-1; App. 8	Rectangle surrounding rwy. Extends 300 ft beyond each end of the rwy. Width is 500 ft, centered on the rwy centerline. (1)
Runway Safety Area (RSA)	AC 150/5300-13, "Airport Design"	¶ 2, 211, 305; Table 3-1; Fig. 3-1; App. 8	Rectangle surrounding rwy. Extends 300 ft beyond each end of the rwy. Width is 150 ft, centered on the rwy centerline. (1)
Obstacle Free Zone (OFZ)	AC 150/5300-13, "Airport Design"	¶ 2, 211, 306; Table 3-1; Fig. 3-2; App. 8	Rectangle surrounding rwy. Extends 200 ft beyond each end of the rwy. Width is 400 ft, centered on the rwy centerline. (2)
Primary Surface	FAR Part 77, "Objects Affecting Navigable Airspace"	§ 77.21, 77.25	Rectangle surrounding rwy. Extends 200 ft beyond each end of the rwy. Width is 1,000 ft, centered on the rwy centerline. (3)
Runway Protection Zone (RPZ)	AC 150/5300-13, "Airport Design"	¶ 2, 201, 211, 212; Figs. 2-1, 2-3; Table 2-4; App. 8	Trapezoid beyond rwy ends. Begins 200 ft beyond rwy end and extends outward 1,700 ft; inner width = 1,000 ft and outer width = 1,510 ft. (4)
Approach Surface	FAR Part 77, "Objects Affecting Navigable Airspace"	§ 77.25	Trapezoid beyond rwy ends. Begins 200 ft beyond rwy end and extends outward 50,000 ft in an upward slope; inner width = 1,000 ft and outer width = 16,000 ft. Passes through the horizontal surface. (5)
Horizontal Surface	AC 150/5300-13, "Airport Design"	Fig. 3-2	Horizontal plane 150 ft above airport elevation. Perimeter is constructed by swinging 10,000-ft arcs from the center of each end of the primary surface of each runway and connecting the adjacent arcs by lines tangent to those arcs. (6)
	FAR Part 77, "Objects Affecting Navigable Airspace"	§ 77.25	
(1) Applies to airplane design group II (2) Applies to runways that can serve large airplanes, i.e. over 12,500 pounds (3) Applies to precision instrument runways; width is 500 feet for runways having only visual approaches (4) Applies to instrument runways having not lower than ¾-mile approach visibility minimums (5) Applies to precision instrument runways; dimensions are smaller for runways having only visual approaches (6) Applies to runways designated as other than utility or visual			

**APPENDIX F – AERIAL PHOTOGRAPH OF RICHARD
LLOYD JONES JR. AIRPORT AND VICINITY**



Source: National Agriculture Imagery Program (NAIP 2003a and 2003b)

**APPENDIX G – ZONING AND PARCELS MAP OF AREA AROUND
RICHARD LLOYD JONES JR. AIRPORT**



Source: Indian Nations Council of Governments (INCOG)

**APPENDIX H – COMPARISON OF LAND-USE ZONES CREATED
FOR THIS STUDY AND FAA LAND-USE CATEGORIES**

Land-use Zone	L _{dn} (dB)	FAA Land-use Categories				
		Residential	Public Use	Commercial Use	Manufacturing and Production	Recreational
A	85+		Transportation		Farming, fishing, forestry, mining, and resources	
B	80-84		Parking	Utilities, wholesale, and certain retail (bldg materials, hardware, and farm equip.)	General manufacturing	
C	75-79		Government services	Business and professional offices, general retail trade, and communication	Photographic and optical	Golf courses, riding stables, and water recreation
D	70-74		Hospitals and nursing homes, churches, auditoriums, and concert halls		Livestock farming and breeding	Parks, camps, and resorts; outdoor spectator sports and amusements
E	65-69					Nature exhibits and zoos
F	0-64	Houses, apartments, mobile homes, and hotels	Schools			Outdoor music shells and amphitheaters

Source: FAR Part 150 (14 CFR Part 150, 2006)

**APPENDIX I – COMPARISON OF LAND USE ZONES CREATED
FOR THIS STUDY AND TULSA ZONING DISTRICTS**

Land Uses Defined in This Study		City of Tulsa Zoning Districts	
Code	Description	Code	Name
A-zone (A1)	Agriculture	AG	Agriculture District
A-zone (A2)	Water and floodplain	n/a	Various use districts, but usually AG
A-zone (A3)	Transportation	n/a	(No equivalent)
A-zone (A4)	Transportation (airport)	IL	Industrial, Light District
B-zone	Industrial, utilities, etc.	IL	Industrial, Light District
		IM	Industrial, Moderate District
		IH	Industrial, Heavy District
C-zone (C1)	Offices and stores	CS	Commercial, Shopping Center District
		CG	Commercial, General District
		CH	Commercial, High Intensity District
		OL	Office, Low Intensity District
		OM	Office, Medium Intensity District
		OMH	Office, Medium-High Intensity District
		OH	Office, High Intensity District
		CO	Corridor District
C-zone (C2)	Golf courses	n/a	Various use districts, but usually AG or RS
C-zone (C3)	Government services	n/a	Various use districts, such as OM, CS, etc.
D-zone (D1)	Parks	n/a	Various use districts, but usually AG
D-zone (D2)	Hospitals and churches	n/a	Various use districts, such as OM, CS, RS, etc.
E-zone	Nature exhibits	CS	Commercial, Shopping Center District
F-Zone (F1)	Residential and hotels	RE	Residential Single-Family, Estate District
		RS-1	Residential Single-Family, Low Density District
		RS-2	Residential Single-Family, Medium Density District
		RS-3	Residential Single-Family, High Density District
		RS-4	Residential Single-Family, Highest Density District
		RD	Residential, Duplex District
		RT	Residential, Townhouse District
		RM-0	Residential Multifamily, Lowest Density District
		RM-1	Residential Multifamily, Low Density District
		RM-2	Residential Multifamily, Medium Density District
		RM-3	Residential Multifamily, High Density District
		RMH	Residential Manufactured Home District
F-Zone (F2)	Schools	n/a	Various use districts, such as RS, CS, AG, etc.
n/a	(No equivalent)	PK	Parking District
n/a	(No equivalent)	CBD	Central Business District
n/a	(No equivalent)	SR	Scientific Research and Development District
n/a	(Varies by use)	PUD	Planned Unit Development
n/a	(No equivalent)	HP	Historic Preservation District

Source: City of Tulsa Ordinances (2006)

APPENDIX J – EFFECT OF JONES AIRPORT ON NEARBY PROPERTY VALUES

While the effects of noise and other externalities are well documented for large, commercial airports, little is known about the effects on smaller, general aviation airports with little or no turbine-powered aircraft operations. To obtain more insight into real estate values around the airport, a sample of assessed property values for residential properties within half a mile of the parallel runways was examined. Cadastral maps and data were obtained at the Tulsa County Assessor's Office. Specifically, ten residential properties within a single subdivision located southeast of the parallel runways were selected from a population of residential properties within the Melody Lane subdivision in the city of Jenks that had been sold between 2000 and mid-2007. The sample selected consisted of five pairs of adjacent properties, with each pair at increasing distances from the runways. It was assumed that selecting properties within the same subdivision would provide more consistency and thereby more meaningful results, although the properties selected fall within three different additions of that subdivision. The first pair of properties was 1,150 feet southeast of runway 1L/19R and the farthest two were at 2,120 feet, so all ten properties were within 1,000 feet of each other.

Only properties that bordered each other were selected as a pair and then their data averaged, including the assessed value. Averaging the data between two properties was believed to provide more representative statistics than relying on a single property. Two bordering properties were used since it was assumed these would be more similar and they could share the same distance from the runway. Although data was selected only from homes sold over a 7½-year period, current assessed values were used in the data

versus the sales price, since this was deemed more up-to-date and accurate. The data is summarized in Table 1 below.

Distance from Runway 1L/19R (ft.)	Assessed Value	Floor Space (sq. ft.)	Value per Floor Space (\$/per sq. ft.)	Parcel Size (sq. ft.)	Value per Parcel Size (\$/per sq. ft.)
1,150	\$137,850	2,516	\$54.79	12,758	\$10.80
1,280	\$119,800	1,709	\$70.10	10,080	\$11.88
1,420	\$125,000	1,579	\$79.16	9,153	\$13.66
1,810	\$144,500	1,992	\$72.54	16,850	\$8.58
2,120	\$124,500	2,011	\$61.91	13,775	\$9.04

Source: Tulsa County Assessor's Office (2007)

Table 1. Average values for five pairs of adjacent residential properties.

While the three averaged pairs indicate rising values as expected, those closest and farthest from the airport deviate from that trend (Figure 1). However, both the averaged value per floor space (Figure 2) and the averaged value per parcel size (Figure 3) do increase for the first three ranges out to at least 1,420 feet, then drop down again in value.

These results are suggestive, but inconclusive, due to the fact that this is a small sample and many factors contribute to a property's assessed value. Proximity to an airport may be considered a disamenity for some residents, but distance from the airport seems to have little impact on values. This analysis was only intended to be informal and was not the central focus of this study. Also, a serious analysis would require a larger sample.

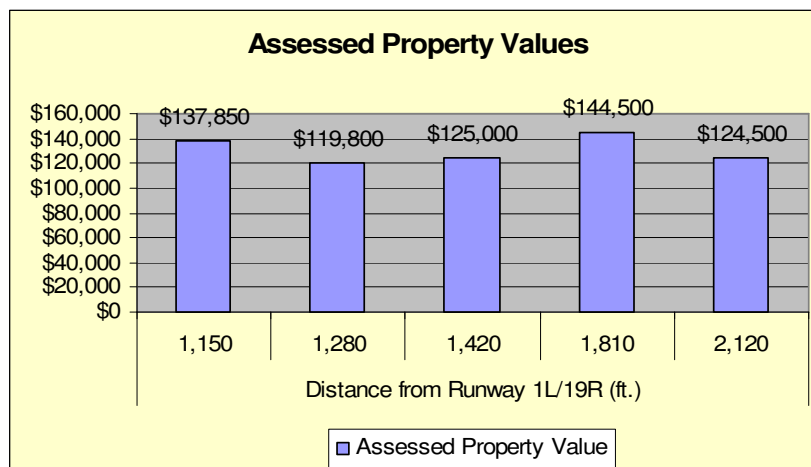


Figure 1. Property values at discrete distances from runway 1L/19R

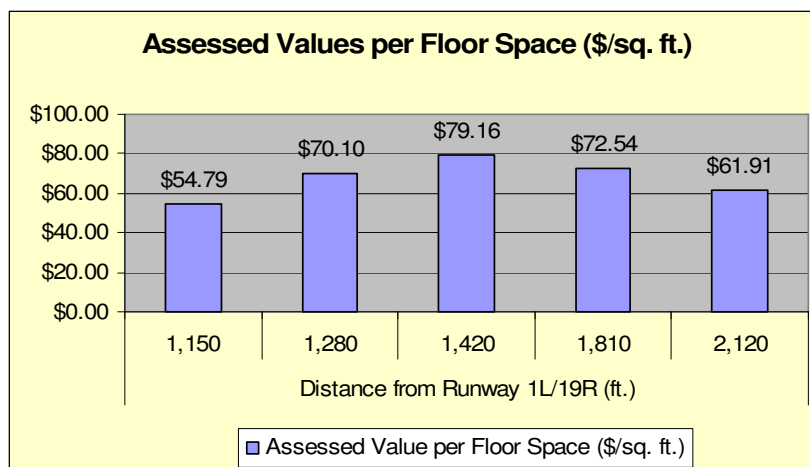


Figure 2. Property values per floor space at discrete distances from runway 1L/19R

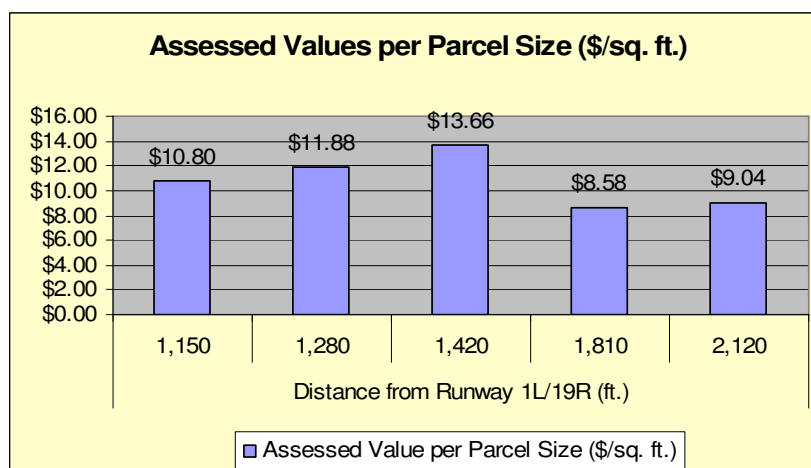


Figure 3. Property values per parcel size at discrete distances from runway 1L/19R

VITA

David Arthur Brockway, Jr.

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE IMPACT OF A GENERAL AVIATION AIRPORT ON
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Pages in Study: 131

Candidate for the Degree of Doctor of Philosophy

Major Field: Geography

Scope and Method of Study: The purpose of this case study was to examine the impact of a general aviation airport on nearby land-use patterns. In particular, it sought to determine the ways in which land use changes with increasing distance from the airport and the extent to which runway orientation influences surrounding land use. Two hypotheses were set forth to address the influence of distance and another two to address the influence of runway orientation on directionality. For each pair of hypotheses, the first one considered the amount of residential and other noise-sensitive land uses, while the second considered population density as an indirect indicator of residential land. A geographic information system was used to create land-use maps, and to analyze both the range and directionality of the airport's influence. The airport selected for this case study was Richard Lloyd Jones Jr. Airport, the busiest airport in Oklahoma. It is situated in the Tulsa metropolitan area.

Findings and Conclusions: Six major research findings resulted from this case study. Of particular note, the results suggest that for this airport the range of the airport's influence extends 2,000 feet beyond the airport boundary. Other significant findings were the lack of a simple gradation of land uses according to distance, the preponderance of agricultural and residential land uses, the close association of industrial land uses with the airport, the fairly even distribution of commercial land uses with distance, and the uncertain results regarding the role of runway orientation on the directionality of nearby land-use patterns.

ADVISER'S APPROVAL: Thomas A. Wikle _____