Airport noise in South Africa – Prediction models and their effect on land-use planning

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Dissertation presented in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Stellenbosch.

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December 2007

AUTHOR’S DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: __________________________

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ABSTRACT

The use of average energy aircraft noise contours as the sole means for guiding aircraft noise-based planning around airports is being questioned increasingly. A growing proportion of residents who live in neighbourhoods adjacent to airports are dissatisfied with the averaging procedure that is employed. In their experience of exposure to aircraft noise, particularly in the evening and at night when they are at home, the average energy aircraft noise descriptors are misleading. In order to effectively analyse the socio-spatial interaction of annoyance at and interference by aircraft noise, an alternative approach has been suggested – a supplemental noise perspective. Conventional approaches to aircraft noise land use planning based on average energy noise descriptors run the risk of being ineffectual, or even counterproductive, because they do not consider the central aspects of disturbance, namely the loudness of an event and the number of times events are heard. Consequently, an alternative measure to ameliorate the limitations of average energy noise contours is needed by which airport neighbours, the aviation industry and town planners can better understand the nature of the problem.

Although supplemental noise analysis is not new, this study applies it to a South African international airport (OR Tambo) for the first time. The airport's operations are typical of many busy airports close to large urban areas, serving domestic, regional and international routes. Reportedly, there have been few complaints about noise emanating from the airport, but when they are made they are usually about evening and night-time aircraft noise events. In the context of South Africa as a developing society in transition, where growth of urban settlements continues apace, average energy aircraft noise information must be enhanced by providing supplemental noise information.

This study investigated the broad issue of land use planning around airports by employing two aircraft noise prediction models, namely the Integrated Noise Model and the Transparent Noise Information Package, to establish the various potential effects and consequences of night-time aircraft noise in noise zones demarcated according to supplemental aircraft noise information. The effects and consequences examined include annoyance, disturbance of sleep, telephone conversations, watching television and work or study, and the likelihood that people will move away to escape night-time aircraft noise. The perceptions of residents living in neighbourhoods around the airport were surveyed and the responses analysed according to noise zones classified as supplemental noise information.

The results show that the airport's neighbours are annoyed by aircraft noise and that aircraft noise interferes with normal household activities. This annoyance and interference decreases with increasing distance from the airport. Furthermore, reported annoyance and interference is greater in those areas where higher numbers of noise events are encountered, even at relatively low noise levels of 60 L_{Amax} – something not evident from average energy noise contours.

This finding strengthens the argument that it is insufficient to provide only average energy aircraft noise information when studying the impact of aircraft noise. To understand the situation more fully, supplemental noise information is essential. The study concludes with a framework constructed to apply supplemental aircraft noise information to the abatement and mitigation measures normally used to deal with aircraft noise.

KEYWORDS and KEY PHRASES

Airport noise, aircraft noise, aircraft noise annoyance/interference, aircraft noise descriptors, average energy noise contours, Integrated Noise Model, Johannesburg International Airport, land use planning, noise abatement/mitigation, noise zones, OR Tambo International Airport, supplemental noise information, Transparent Noise Information Package.

OPSOMMING

Die gebruik van gemiddelde energie geraaskontoere as die enigste manier om vliegtuiggeraas-gebaseerde beplanning rondom lughawens te rig, word in toenemende mate bevraagteken. Al hoe meer inwoners in die omstreke van lughawens is ontevrede met die aweryprosedure wat gevolg word. Hulle ervaring van blootstelling aan vliegtuiggeraas – veral in die aand en nag – getuig daarvan dat die gemiddelde energie geraasbeskrywers misleidend is. Om die sosiaal-ruimtelike interaksie van ergenis met en steuring deur vliegtuiggeraas effektief te ontleed, is 'n alternatiewe benadering al voorgestel, naamlik 'n aanvullende geraasperspektief. Konvensionele benaderings tot grondgebruikbeplanning wat vliegtuiggeraas oorweeg, loop die gevaar om ondoeltreffend, selfs teenproduktief, te wees omdat hulle nie die sentrale aspekte van steuring, naamlik die luidheid van 'n gebeurtenis en die aantal kere wat dit gehoor word, in ag neem nie. Gevolglik word 'n ander maatstaf benodig om die beperkings van die gemiddelde energie geraaskontoere te verbeter sodat die lughawe se bure, die lugvaartindustrie en stadsbeplanners die aard van die probleem beter kan verstaan.

Ofskoon aanvullende geraasanalise nie nuut is nie, word dit in hierdie studie vir die eerste maal op 'n Suid-Afrikaanse internasionale lughawe (OR Tambo) toegepas. Die lughawe se werksaamhede is soortgelyk aan baie ander bedrywige lughawens naby groot stedelike gebiede wat binnelandse, streeks- en internasionale roetes bedien. Volgens berig, word min klagtes oor geraas afkomstig van die lughawe ingedien, maar wanneer dit wel gebeur, handel dit meesal oor vliegtuiggeraas saans en snags. In die konteks van Suid-Afrika as 'n ontwikkelende en transformerende gemeenskap met stedelike gebiede wat aanhou snel groei, moet gemiddelde energie vliegtuiggeraasinligting deur aanvullende geraasinligting versterk word.

Hierdie studie het die breë kwessie van grondgebruik rondom lughawens ondersoek deur twee modelle vir vliegtuiggeraasvoorspelling, naamlik die Geïntegreerde Geraasmodel en die Deursigtige Geraasinligtingspakket, in te span om die verskeie potensiële effekte en gevolge van nagtelike vliegtuiggeraas in geraassones afgebaken volgens aanvullende vliegtuiggeraasinligting, vas te stel. Die effekte en gevolge wat ondersoek is, sluit verergdheid, die versteuring van slaap, telefoongesprekke, televisiekyk en werk- of studiebedrywighede in, asook die waarskynlikheid dat mense sal wegtrek om nagtelike vlietuiggeraas te ontvlug. 'n Opname oor die persepsies van inwoners in die buurte rondom die lughawe is uitgevoer en die response is volgens geraassones geklassifiseer as aanvullende geraasinligting.

Die resultate toon dat die lughawe se bure versteur is deur vliegtuiglawaai en dat die geraas by normale huishoudelike aktiwiteite inmeng. Hierdie ergenis en steuring neem af met toenemende afstand vanaf die lughawe. Verder is vasgestel dat die vermelde versteuring en inmenging groter is in dié gebiede waar meer geraasvoorvalle plaasvind, selfs teen relatief lae geraasvlakke van 60 L_{Amax} – iets wat nie blyk uit gemiddelde energie geraaskontoere nie.

Hierdie bevinding ondersteun die argument dat dit ontoereikend is om slegs gemiddelde energie vliegtuiggeraasinligting by die bestudering van die effekte van vliegtuiggeraas te gebruik. Aanvullende geraasinligting is noodsaaklik vir beter begrip van geraastoestande. Die studie sluit met 'n raamwerk waarmee aanvullende vliegtuiggeraasinligting aangewend kan word by die geraasverminderings- en verligtingsmaatreëls wat normaalweg ingespan word om met vliegtuiglawaai te handel.

SLEUTELWOORDE EN -FRASES

Aanvullende geraasinligting, Deursigte Geraasinligtingspakket, ergenis met/steuring deur vliegtuiggeraas, Geïntegreerde Geraasmodel, gemiddelde energie geraaskontoere, geraassones, geraasvermindering, geraasversagting, grondgebruikbeplanning, Johannesburg Internasionale Lughawe, lughawegeraas, OR Tambo Internasionale Lughawe, vliegtuiggeraas, vliegtuiggeraasbeskrywers

ACKNOWLEDGEMENTS

I should like to thank the following people:
My supervisor, Prof HL Zietsman, for his advice, guidance and patience, particularly for continuing to work with me after taking retirement.

Dr P De Necker for his patient editing.

Air Traffic and Navigation Services (ATNS) for providing the air traffic movement data.

Ekhuruleni Metro for providing the GIS land-use data and other valuable insights.

The staff at the Department of Geography and Environmental Studies, Stellenbosch University, for their assistance.

My colleagues, Kobus Reynecke, Andre Bruton and Allen van der Linde for their technical support.

My family, parents Eddie and Barbara; wife Jane; and children David, Sarah, Danielle and Michael for all their understanding and encouragement.

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ACRONYMS

EIA	Environmental Impact Assessment
FAA	Federal Aviation Administration
GPG	Gauteng Provincial Government
IDZ	Industrial Development Zone
IEM	Integrated Environmental Management
INM	Integrated Noise Model
L_{Aeq}	A-weighted Equivalent Level
L_{Rdn}	Day Night Rating Level
SABS	South African Bureau of Standards
SANS	South African National Standard
SAST	South African Standard Time
SDF	Spatial Development Framework
TNIP	Transparent Noise Information Package
UDB	Urban Development Boundary
UT	Universal Time

CHAPTER 1: AIRCRAFT NOISE: AN ENVIRONMENTAL PROBLEM

1.1 BACKGROUND AND RATIONALE FOR THE STUDY.

The last one hundred years have been the urban century, in that the phenomenon of growth of cities and urban areas has been one of the most remarkable geographical social and economic features (Badcock 2002; Miller 2005 & Nagle 2000). High urban population densities have led to the problem of what to do about the environmental impacts of cities on their residents, surrounding countrysides and even their larger global footprint. Environmental management in First World cities is currently geared to waste reduction and recycling, and eventually dumping whatever is left over. In developing countries, less emphasis is placed on waste reduction and recycling – most solid waste is just dumped. However, environmental management goes far beyond simple waste management. Badcock (2002) maintains that citizens in more developed countries are demanding that cities as living environments meet higher expectations with respect to quality of life. Urban managers are having to confront more planning issues to satisfy citizens that the planning and design of cities are environmentally sustainable.

Spatial configurations of cities produce effects which may affect social behaviour and interaction (Massey 1999). The adverse effects of pollution and waste creating activities are not the only negatives that residents have to suffer. Residents also have to contend with noise from road traffic, trains, rowdy neighbours, pets and aircraft. Whilst other environmental hazards, such as the supply and removal of water and sewage, the production and disposal of solid waste and air pollution are more pervasive, the generation of harmful noise also has a negative impact on the health and wellbeing of city dwellers. In more and more of the world's cities, people are becoming increasingly aware of the nuisance of intrusive and even harmful noise. These changes in public perception of noise have not occurred as isolated social phenomena. For example, opposition to nuclear power began to grow in the 1970's and there are mounting concerns about global climate change and its consequences (Stallen & Compagne 2006).

Excessive noise levels can lead to hearing damage, but other unpleasant effects occur, for example sleep disturbance and interference with work and recreation, sometimes leading to a desire to move away from the area to escape the disturbance. Badcock (2002) identifies four main sources of noise pollution in urban environments namely industrial equipment, construction work, road traffic and aircraft. Many of the world's international airports are situated in densely populated urban areas. People living in neighbourhoods in London, New York, Los Angeles and Mexico City, close to airport approach and departure flight paths have to put up with the continuous noise of aircraft landing and taking off (Hardoy, Mitlin & Satterthwaite 2001).

The transport of goods and people has been vital for the growth of cities (Nagle 2000) since transport matches the supply of goods, materials and services with the demand for them. Transport modes like air, pipelines, rail, road and water all have a variety of impacts on the environment. The major environmental impacts of air transport are engine emissions and aircraft noise, and since the introduction in the late 1950's of the first commercial jet aircraft – the British Comet, the American Boeing 707 and McDonnell-Douglas DC-8 - there have been dramatic changes in the nature and magnitude of the airport noise problem (Ashford & Wright 1979; Brennan, Orth, Conner & Schwartz 1991). Significantly, noise is by far the most frequently mentioned disamenity in the home (Organisation for Economic Co-operation and Development 1986).

The major atmospheric pollutants are carbon, sulphur and nitrogen oxides, volatile organic compounds and suspended particulate matter. Although not often regarded as a major atmospheric pollutant, noise can be regarded as an atmospheric pollutant since noise depends on the ability of air to transmit sound waves (Haughton & Hunter 1994).

Communities living in the vicinity of airport flight paths have a long-standing interest in the noise emitted from aircraft as they land or takeoff and authorities around the world have attempted to manage the negative impact of noise from these aircraft operations. The Organisation for Economic Co-operation and Development (1986) has reported that there are many ways of combating the disamenity of aircraft noise. These can be classified into three categories: firstly, noise can be reduced at source, i.e. make aircraft engines quieter; secondly, the impact of noise can be averted by preventing it from reaching the receiving environment, i.e. keeping airports and residential land-uses far apart; and thirdly, it is possible to increase the protection provided by the receiving environment e.g. double-glaze windows in exposed housing. Perhaps the most co-ordinated attempts have been the efforts of the International Civil Aviation Organisation (ICAO) – a division of the United Nations (UN). In 2001, the General Assembly of ICAO endorsed the concept of a balanced approach to aircraft noise management. This consists of four principal elements, namely:

- reduction of noise at the source (engines and airframe improvements),
- land-use planning and management,
- noise abatement operational procedures,
- operating restrictions (International Civil Aviation Organisation 2004).

Of these methods, the one with the greatest relevance to geographers is land-use planning and management. The problem of airport noise is a function of the location and size of an airport, and the built-up areas under the flight paths. Land-use controls informed by accurate delimitation of noise exposure zones is one way of resolving the problem (Pacione 2001).

For land-use planning purposes worldwide, 'average energy noise contours' are produced to represent aircraft noise around airports. The contours are based either on actual measurements of noise made by landing and departing aircraft, or on computer modelling of aircraft noise, and are known as 'average energy contours' since the total amount of aircraft noise is distributed over a defined time period, usually 24 hours. The 'average energy noise' contours have been linked by sociological surveys to the annoyance levels that residents and other land-users around airports display so that aircraft noise contours can be used in the town planning and land management process. Examples of average energy noise descriptor terms in use around the world are Noise Exposure Forecast (NEF, Canada), Day-Night Average Sound Level (DNL, USA), Community Noise Equivalent Level (CNEL, California), Psophic Index (IP, France), Noise and Number Index (NNI, Ireland), Weighted Equivalent Continuous Perceived Noise Level (WECPNL, Japan), Leq (United Kingdom) and Day Night Rating Level (L_{Rdn}, South Africa). These terms refer to noise levels measured or computed over a long period of time (usually a year). They are sometimes called 'cumulative noise' or 'noise exposure' because they can either be viewed as sums or as averages over time (Timmermann 2005). They are based on total (average) numbers of flights at average wind and weather conditions on allocated (average) runway use conditions. Because they represent all the varied conditions, they are useful in planning and in regulation. The major criticism of average energy contours is that there is rarely a real day which is average in all those ways.

Noise contours are superimposed onto land-use planning maps, and the boundaries of the contours used to determine and delineate the spatial extent of the spread of aircraft noise. The noise calculation methods are accompanied by a table describing the types of land-uses permitted in or to be excluded from the noise zones. For example, in the USA, the compatible land-use table is contained in the Federal Aviation Administration's FAR Part 150 (United States General Accounting Office 2000). In South Africa, the Standards South Africa document *SANS 10103 The measurement and rating of environmental noise with respect to land use, health, annoyance and to speech communication* (Standards South Africa 2004) gives guidance on noise and land-use.

For over three decades the South African Bureau of Standards and more recently the restructured Standards South Africa – a division of the South African Bureau of Standards have compiled codes and standards (see South African Bureau of Standards 1974; Standards South Africa 2003 and 2004) used to calculate and delineate where, and what type of development can take place around airports. The recently revised Standards South Africa system (SANS 10117) continues to provide guidance in this role (Standards South Africa 2003). Updates of SANS 10117 include the requirement that the Integrated Noise Model (INM) aircraft noise modelling computer program be used to calculate noise contours around airports, and includes reference to new land-use planning guidelines contained in the SANS 10103.

The INM is developed by (and available from) the United States' Federal Aviation Administration Office of Environment and Energy. It is widely used by the civil aviation community for evaluating aircraft noise impacts in the vicinity of airports and the author set up and used this model to further the aims of the study.

Until 2002, the SABS 0117 standard, and since 2003 the SANS 10117 and SANS 10103 standards, have been used in three key ways. They have been used to delineate where, and what type of development can take place around airports; for technical assessments of airport operating options in environmental impact assessments; and as tools for providing information to the public on noise exposure patterns around airports. For example, SANS 10103 recommends an L_{Rdn} level of 45 should not be exceeded in rural areas, 50 in suburban districts, and 55 in urban districts.

These standards have been useful in land-use planning, and the SANS 10117 and 10103 systems will continue to play an important part in guiding land-use planning. However, there are significant limitations in using the SANS 10117 system to describe aircraft noise to the non-technical person. Many noise complaints are now coming from people who live outside the 55 L_{Rdn} contour. Traditionally, these residents have been given little or no information on aircraft noise. Most people living outside the 55 L_{Rdn} contour have an expectation of being subjected to little or no aircraft noise – those seeking the peace and quiet of a rural environment find the levels of aircraft noise experienced to be unacceptable.

Van Heerden (2000) reported that residents in Pretoria's eastern suburbs were complaining about contending with high noise levels caused by commercial air traffic departing OR Tambo International Airport[1] (ORTIA) for long-haul destinations in the

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[1] The city of Johannesburg is at the core of South Africa's major metropolis. Two points of clarification are required. First, a distinction must be made between the city of Johannesburg per se, and its growing metropolitan region, itself composed of several autonomous but interconnected municipal authorities, one of which is Ekhuruleni, in which the Johannesburg International Airport is located. Johannesburg, and all of its surrounding municipal authorities will be collectively referred to as Metropolitan Johannesburg, or "Johannesburg" after Beavon (1998) and Rakodi (1998). Second, during the latter stages of authoring, Johannesburg International Airport (JIA) was renamed to OR Tambo International Airport (Pressley 2006), and so these names may be used interchangeably.

northern hemisphere. Even though these residents lived some distance outside ORTIA noise contours, they were annoyed by aircraft noise. This issue is not unique to South Africa. In Australia, the Australian Noise Exposure Forecast (ANEF) of 20 is the value below which areas are acceptable for housing (Airservices Australia 1996). In 1998, the Australian Department of Transport and Regional Services reported that at Sydney Airport over 90 per cent of the complaints came from residents in areas outside the 20 ANEF contour (Commonwealth Department of Transport and Regional Services 2000).

Since 1996 the author has been a member of the Airport Environment Committee (AEC) at ORTIA. There have been two constant complaints tackled at the committee meetings over the years, namely from those residents who complain about night-time aircraft noise, and those from people who live to the north of the airport and outside the land-use planning contour being disturbed by aircraft noise. The fact that people who live outside the noise contours are being disturbed by aircraft noise has led, in recent years, to suspicion about and mistrust of the validity of the contours.

This leads to a pertinent question regarding the South African context, namely the role 'average energy' aircraft noise contours (calculated according to the SANS 10107 standard) have in land-use spatial planning for neighbourhoods in the vicinity of airports. It would appear that SANS 10107 needs to be enhanced to provide a basis for the provision of better information to address the issues of aircraft noise that arise at South African airports.

1.2 RESEARCH PROBLEM: LINKING AIRCRAFT NOISE AND LAND-USE PLANNING

It has been established that aircraft noise disturbs communities around airports. To counter the problem, noise contours are produced by acoustic experts, consultants and airport authorities for use by town planners with the intention that the planners will use the contours to keep noise sensitive land-uses and airport noise impacted areas apart. Average energy noise descriptors, usually used in association with land-use planning guidelines, are designed as a system or methodology to provide a consistent, repeatable way of producing aircraft noise contours. Average energy aircraft noise descriptors were initially intended for use by the authorities (for example town planners) as an input into the land-use planning process. With time, the use of the contours has evolved. Contours now also tend to be used by authorities to “prove” to people who complain about aircraft noise that they do not have a problem (Commonwealth Department of Transport and Regional Services 2000).

While the merits of average energy noise descriptors, which have been stated above, help bureaucratic decision-makers establish guidelines for land-use planning, reducing noise exposure to a single value of L_{Rdn} does not convey to the public the extent of the aircraft noise impact because L_{Rdn} masks the number of events, and the peaks in noise level experienced. People hear individual aircraft noise events – they do not hear an average, and it is the individual peak noise levels which cause complaints.

From the foregoing introduction, it can be postulated that supplemental[2] information about aircraft noise has a role to play in the planning framework that town planners use and in keeping residents who live around airports informed about aircraft noise.

1.3 RESEARCH AIM AND OBJECTIVES

The aim of this study is to investigate the broad issue of land-use planning around airports by employing two aircraft noise prediction models, namely the Integrated Noise Model and the Transparent Noise Information Package to establish the various potential effects and consequences of night-time aircraft noise, in noise zones demarcated according to supplemental aircraft noise information. The effects and consequences include disturbance of sleep, telephone conversations, television viewing and work or study and the likelihood that people will move away to escape night-time aircraft noise.

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[2] Stein (1971: 1429) defines supplemental as ‘… added to furnish what is lacking or missing.’ A ‘supplemental noise descriptor’ in this study refers to additional information about aircraft noise.

Specific objectives are to

- Examine aircraft noise and land-use planning literature and practise, and determine the conceptual links between the two fields (Chapter 2: Literature review/theoretical framework).
- Expose the confusion that different average energy noise contour calculation methodologies can create (L_{Aeq}, DNL, NI and L_{Rdn}) (Chapter 3: Research design and methodology).
- Establish that communities experience annoyance from aircraft noise even when they are located outside 55 L_{Rdn} aircraft noise contours (Chapter 4: 'Average energy results).
- Calculate a 12-hour night-time 'average energy' contour for a South African airport (Chapter 4: 'Average energy' results).
- Calculate supplemental aircraft noise information in the form of 'number of events' above specified thresholds (Chapter 5: Supplemental noise information)
- Devise an inclusive airport noise and land-use planning framework to be used around new or existing airports. The present study will propose the possibility, as a new social practice, of making digital aircraft noise spatial data available in a format easily understood by the layperson to communities around airports. (Chapter 6: An inclusive airport noise and land-use planning framework).
- Draw salient conclusions and make relevant recommendations (Chapter 7: Conclusions and recommendations).

Geography as a field of study can be very broad. The following section draws links between geography, urban planning and aviation noise.

1.4 THEORETICAL FRAMEWORK: PHILOSOPHY OF GEOGRAPHY AND THE URBAN PLANNING-AIRCRAFT NOISE LINK

The introduction made clear how noise, specifically aircraft noise, is a problem in the vicinity of airports. It was pointed out that informed land-use planning in the vicinity of airports is one way of reducing aircraft noise disturbances. The question that arises is where the domains of aircraft noise and land-use planning lie in the theoretical framework of geography, the discipline in which this research is to be conducted?

The debate about pollution in an urban context is very relevant to geographers. Human geography focuses on the social (human) landscape but is open to a cross-disciplinary focus (Haggett 1990; Massey 1999) in which practical geography is simultaneously spatial, natural and social (Smith 2004).

In the following sections the links between geography and noise, and aircraft noise as environmental problems are explored.

1.4.1 Aircraft noise studies in the context of geography

The field of geography covers a vast range of topics and interactions and conflicts between topics. Indeed, Heffernan (2003) states that geography has always been in a state of uncertainty and flux, but argues that the absence of conceptual conformity has been one of the discipline's strengths. All disciplines are prone to shifts in focus and methodology, and geography is no exception (Barnard 2001). A study of the literature about the discipline of geography yields a multitude of viewpoints, and it is quickly apparent that there is no single umbrella definition. Over the years, geography has evolved from the classical geography of Eratosthenes' *gê* (earth) and *grapheïn* (to draw or write) to environmental determinism, through modernism, to postmodernist contemporary geography through the renewal of the discipline after the 1950s to humanism and on to a specialist phase where geographers were specialists in one or other branch of the subject and research competence and output were the criteria on which they assessed themselves (Barnard 2001).

Haggett (1990) writes that geographers are concerned with finding the pattern, structure and meaning that lies in the world's regional diversity at all scales. Cresswell (2004) in turn argues that being informed by place involves more than simply writing about a place. It involves thinking about the implications of the idea of place for whatever it is being researched. Place can have a double meaning (Harvey 1996). It can be the position of a location on a map, or an entity. Soja (1999) encourages a different way of thinking about space as rather an open-ended set of defining moments. He describes an ontological shift from temporal and social characteristics to the ontology of human existence. The spatiality of being and becoming is beginning to be recognized more than before, injecting an assertive term of spatiality-sociality-historicality into the ontology of human existence. Stated differently, the social production of spatiality or the making of geographies is becoming fundamental to understanding our life worlds (Soja 1999).

It can be argued that the study of aircraft noise and land-use around airports constitutes an endeavour to find Haggett's pattern and structure. The present study acknowledges Soja's way of thinking about space in the search for supplemental aircraft noise information in the space around airports.

"Urban geography is an established branch of geography … to aid our understanding of the city" (Pacione 2001: 26). From the 1970s, the scope of urban geography has expanded rapidly. Some writers believe that the increased diversity is a source of weakness whilst others believe the breadth of the perspective strengthens urban geography's position as an integrative focus for research on the city (Pacione 2001). Hence, urban geographers have approached the study of cities from a number of philosophical perspectives. Pacione, (2001) lists some of the main epistemological developments of urban geography, namely environmentalism, positivism, behaviouralism, humanism, structuralism, managerialism, postmodernism and moral philosophy. He also rejects the view of those who "… insist on the need to make a unitary choice of theoretical framework due to the perceived superiority of a particular theory of knowledge." and instead favours a combination of approaches in different ways which "… incorporates a search for a middle ground between the generalization of positivism and the exceptionalism of postmodern theory." (Pacione 2001: 26)

The importance of employing a combined multi-layered 'realist' perspective (Pacione 2001) that encompasses the global and local scales, social structure and human agency, and theory and empirical investigation in seeking to interpret the city will inform this research.

To study urban geography is to study the living environments of more than half the world's population. Although there are exceptions, living conditions in urban areas in the First World are generally better than in the developing world, one of the reasons being good planning. South Africa is striving to attain the characteristics of a modern developed country. The greater Johannesburg urban agglomeration is one of the core urban areas at the forefront of this striving, and faces its share of common problems, particularly pollution. Noise, defined as unwanted sound, is one of the most ubiquitous urban pollutants and most urban dwellers are subjected to noise pollution (Miller 2005). Possible adverse effects of noise include annoyance, sleep disturbance, health problems, disruption of television viewing and other entertainment, effects on job performance, and property value reductions. Serious noise nuisance can be created between multi-occupancy buildings such as flats and offices. Outdoor sources of noise include construction and industry, but the most persistent is transportation noise which includes road, rail and noise from aircraft landing and taking off. Resolution of the aircraft noise problem requires a combination of technical improvements to aircraft airframes and engines, insulation of dwelling units near flight paths, and land-use planning informed by accurate delimitation of aircraft noise exposure zones. Geographical research is ideally positioned to integrate all of these requirements, and then determine optimal planning and flight route solutions which limit noise exposure.

‘Place’ is a term frequently used to describe some aspect of geographical study. The vision of place could, for example, be cultural, ecological or economic. The present study will treat place as areas to be emphasised – those areas around an airport, near the flight paths of aircraft where residents have to endure aircraft noise which makes their place less nice to live (Cresswell 2004). The research methodology followed in this approach is postmodernist to an extent where the viewpoints of diverse individuals are considered, and follows the epistemology of a combination of environmentalism and positivism.

A research agenda is an inventory of problems which justifies the research – dysfunctions in urban society in which the researcher happens to have an interest. The current problems of a particular society at a particular time will attract research interest. In the present study there are overlaps with other disciplines, for example socio-psychoacoustics is one and aeronautical engineering another, but this study is viewed as a human-environment one, the environment in this instance being the pollution of the soundscape to which at the local neighbourhood level of analysis residents are exposed. If noise can be regarded as a hazard, then residential location within a noise zone around an airport could be regarded as being in a hazardous zone. Living in or developing residential dwellings in noise zones are then to be avoided.

Pacione (2001) mentions the epistemologies of behaviouralism and managerialism. Behaviourism comes into the present study when the key question of how people respond to an environmental pollutant, in this case noise from aircraft is addressed. A survey to gauge annoyance and interference from aircraft noise will be administered. Managerialism, in turn comes into play when it will be examined how bureaucratic gatekeepers – those who are responsible for the laws and standards, and administering them (national government, Standards South Africa, local authorities) – control how land resources are used.

A number of philosophical approaches have been mentioned earlier. No single approach in the present study will provide an explanation of the aircraft noise pollution phenomena under investigation. The question is whether a convenient accommodation is possible among the different approaches. The researcher accepts a pluralist stance – that there is no single way to gain knowledge (Pacione 2001: 31). The route which incorporates a search for a middle ground between behaviouralism, positivism and managerialism is the approach favoured here.

Barnard (2001) and Unwin (1992) are of the view that the trend toward the division of geography into distinct physical and human parts will eventually fall away. Unwin (1992) foresees specific social science and earth science departments with an increasing interdisciplinary context, while Barnard (2001) sees a holistic, flexible and applied environmental geography, and a diffuse holistic geography. Unwin (1992) expresses the concern that the human utilization of the environment, and particularly pollution control, require a cross-disciplinary knowledge of physical processes and social practice. An understanding of them can only be partial if approached purely from either the physical or the social sciences. Geography has a long tradition of research about the human occupation of the Earth and a tackling of the issues facing contemporary society. This study will attempt to interpret the coming together of the objective and subjective worlds of reality. Place has become a focus for understanding the interaction of the human world of experience and the physical world of existence.

Space is the fundamental stuff of human geography – it divides and connects things into different kinds of collectives which are slowly provided with the means which render them durable and sustainable (Thrift 2003). In this study the 'things' he refers to are: (i) the aeronautical engineers working on technical solutions to reduce noise from aircraft whilst at the same time balancing the requirements for safe flight, reducing fuel consumption and emissions; (ii) the pilots flying the aircraft and attempting to do so safely and as quietly as possible; (iii) the noise from aircraft; (iv) residents on the ground living in the vicinity of flights paths around an airport whose television viewing, telephone conversations, sleep and work are disturbed by aircraft flying overhead; (v) land-use planners attempting to accommodate the demand for more land in a rapidly growing urban context. All of these result in the collective of an aircraft noise problem which needs to be provided with solutions that are durable and sustainable.

The analytical value of employing the different theoretical perspectives raised so far is illustrated in Table 1.1 with reference to the question of urban land-use in the vicinity of flight paths around airports, and the resulting aircraft noise pollution. The importance of employing a combined 'realist' perspective that encompasses the local scale of urban studies informs the organization and content of this study.

Table 1.1: Analytical value of different theoretical perspectives in urban geography applied to aircraft noise

Theoretical perspective	**Interpretive insight**
Environmentalism	The influence of environmental factors on residential location can be seen in the problems of aircraft noise in neighbourhoods around airports.
Positivism	Uses statistical analysis of subjective responses to aircraft noise to reveal areas around airports with aircraft noise characteristics which affect residential developments.
Behaviouralism	Addresses the key question of how people are disturbed by aircraft noise and what their response may be.
Humanism	Explains how different social groups interact with noise from aircraft. In the present study, survey responses of two groups will be considered: suburb and township.
Managerialism	Illustrates how urban residential structure is affected by the ability of local planning authorities to control development which is inappropriate for the relevant aircraft noise levels.
Postmodernism	Explores the place of population groups of different socioeconomic status in the community. Generally township residents are less wealthy than suburb residents. How does this affect their perceptions of aircraft noise and their priorities for local development.
Moral philosophy	Critically evaluates the ethical underpinnings of issues such as locating less wealthy communities in areas around airports which are affected by aircraft noise.

Source: Adapted from an idea by Pacione (2001: 32).

1.4.2 Using Geographical information systems (GIS) in aircraft noise studies

GIS can best be described as a computer information system capable of entering, manipulating, analysing and displaying geographically referenced data. GIS is well suited to analyse data of a spatial as well as a non-spatial nature (Zietsman 1991). The location of the loudness of an aircraft taking off or landing at a point on the ground is, for example, spatial in nature while the type of aircraft, type of operation and time of the flight are the non-spatial features of the flight. GIS also allows the researcher to transfer data from other software packages or extract data for the purpose of analysis.

Being an applied and environmentally focused approach, the output of airport noise contouring software may be regarded as a simple type of GIS, well suited to cartographic presentation in a more comprehensive GIS. Aircraft noise information by itself is almost useless. Once it has been overlaid onto a land-use map it becomes much more relevant. From here it is easy to take the next step to making the noise information available and transparent. Making transparent aircraft noise information available has a democratising potential within informatics. Informed open discussion is mobilised through providing more information and access to information and provide tools for sustaining and enlarging opportunities for 'voice' and 'access' in an arena of reasoned, open, un-coerced discourse (Pickles 2004).

1.4.3 The Aarhus Convention: access to aircraft noise information and public participation

The Aarhus Convention (adopted by the United Nations Economic Commission for Europe in the Danish city of Aarhus in 1998) developed out of Agenda 21, and concentrates on linking environmental rights and human rights (United Nations Economic Commission for Europe 2006). Access to information about the environment by the public is a particular aspect which is stressed in the convention, and which will be discussed later in this dissertation where the possibility, as a new social practice, of making digital aircraft noise spatial data available in a format easily understood by the layperson to communities around airports will be explored.

1.4.4 Airport noise

For Barnard (2001:5), geography is a discipline which "… represents a specialized way of looking at the earth's surface, collecting facts, transforming them into concepts and addressing problems." If airport noise is regarded as a problem, then the question may be posed: How may geography be used to process the information and address the problem?

To illustrate the way the SABS and SANS standards have been used as an information tool, it is useful to examine the type of information usually given to people who are interested in learning about aircraft noise perhaps because they are town planners or developers, or perhaps because they are disturbed by the noise from aircraft operations. They are generally shown a land-use planning map with the aircraft noise contours superimposed on the map. They then find the location of the property or area in which they are interested, and the corresponding aircraft noise level (for argument's sake say below 55 L_{Rdn}). If any further advice by an aviation or local authority official is given, it usually relates to the objectivity of the assessment of the noise in the area according to national standards. The advice is not very enlightening – the advice has merely told the enquirer that a national standard has determined that they would not be disturbed by noise should they move into those houses in question. It may even be interpreted that there is no aircraft noise at those properties. It is therefore possible, and likely that people form the opinion that aircraft noise would only be a problem for properties inside the contours.

Recent experience, however, has demonstrated that the aircraft noise problem is not confined to areas inside the contours (Commonwealth Department of Transport and Regional Services 2000; Fidell 1999). People hear individual aircraft – they do not hear an average, and individual aircraft are heard for some distance outside the spatial extent of average energy noise contours.

Some land-use planning which has been done around airports was based on the spatial extent of the boundaries of noise contours produced by the SABS over the years. The SABS Noisiness Index (NI) system was developed in the early 1970s. Since then the NI contours, as an aircraft noise information and land-use planning system, grew to the point that the contours excluded all other ways of reporting aircraft noise exposure. In recent years there has been public dissatisfaction with average energy contours. Other average energy noise descriptors, notably the DNL in America and the ANEF in Australia have also come under criticism (Commonwealth Department of Transport and Regional Services 2000; Federal Interagency Committee on Aviation Noise 2002).

The shortcomings of the way the average energy noise contours have been used to provide aircraft noise information for communities and for land-use planning, and the strategies to address these, are the foci of this dissertation.

1.4.5 Noise as an urban environmental problem

The World Health Organisation defines ‘community noise’ (also called ‘environmental noise’, ‘residential noise’ or ‘domestic noise’) as noise emitted from all sources except noise at the industrial workplace, the main sources including road, rail and air traffic, and the neighborhood (Berglund, Lindvall & Schwela, 1999). According to Berglund, Lindvall & Schwela (1999), noise has always been an important environmental problem for human beings. As far back as ancient Rome and Medieval Europe rules existed to limit the noise from ironed wheels of wagons and horse-carriages during night-time to ensure a peaceful sleep for inhabitants.

Negative effects of noise include interference with communications; noise-induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses; effects on social behaviour; reduction in property values and noise induced ghettos (Berglund, Lindvall & Schwela, 1999). The nature of activities in urban areas means that more noise is created, and more people are affected because of the high density of people living in these areas.

Aircraft noise is the focus of this study and in the next section, techniques which are in use to minimise aircraft noise will be discussed.

1.4.6 Techniques used to minimize the aircraft noise problem

Four techniques are commonly used to counter the problem of aircraft noise, namely

- use of technology to design and manufacture quieter aircraft (including quieter engines and improved airframe design)
- noise abatement (meaning that pilots take measures to operate the aircraft as quietly as is safely and operationally possible)
- noise mitigation (meaning reducing noise at the recipient, such as acoustic insulation of buildings)
- land-use zoning.

Local authorities are able to control development of various parcels of land around airports through noise zoning, the goal being to keep development, which is incompatible with aircraft noise away from the airport. It is in this area that geography has a promising contribution to make in dealing with the aircraft noise problem (Morgan 1999, Vowles 2006).

1.5 NOISE EXPLORED

1.5.1 What is noise?

It is necessary to explain what is understood by the term noise before investigating the impact of aircraft noise. The *Encarta world English dictionary* defines noise as “Unpleasant sound, a loud, surprising, irritating or unwanted sound” (Rooney, Carney, Soukhanov, Jellis, Clarke & Yates 1999: 1285). Other authors describe noise as: “… one of the environmental problems festering in the cities… ” (Bragdon, 1973:15); “… a source of great annoyance, interrupting sleep, interfering with conversation, and depriving people from full enjoyment of many recreational activities …” (Ashford & Wright 1979: 410) “… the intrusion of unwanted, uncontrollable, and unpredictable sounds.” (Bronzaft 2004: 66); “… excessive or unwanted sound that is unwanted because it annoys people, and one of the most common forms of pollution … noise can be defined as unwanted sound waves that were not present in the pre-modern electromagnetic spectrum.” (Duckworth & Frost 2004: 2783). The general message is that noise is something which is irritating and annoying and to be avoided.

Noise is measured in units known as decibels, abbreviated to dB. Noise can range from 1dB (which is near silence) to 140dB which could be made by military jet aircraft. A sound level meter is the instrument used to measure noise levels in decibels.

1.5.2 What is aircraft noise?

In 1911, when aviation was in its infancy, noise from aircraft was already receiving attention. "Taking everything into consideration, there is little to be lost by silencing and a great deal to be gained…. we may rest assured that the tremendous racket that is at present associated with the aeroplane, plays a considerable part in prejudicing the public against these machines." (*The Aero* 1911: 1).

Large technological advances have been made since the 1960s in reducing the noise made by transport aircraft. Aircraft and engine manufacturers continue with research to increase the noise reductions, even as aircraft become larger. These include an ultra-quiet blended wing-body airliner so quiet it can only be heard within the airport boundary (Coppinger 2005); aircraft engine manufacturer CFM International acknowledging that "… there is huge pressure on noise … ." and that "… a breakthrough is needed in terms of technology …" (Norris 2005a: 60); and Boeing recommending the use of engine chevrons that help mix fan and core exhaust streams with bypass flow thereby reducing shear and noise (Norris 2005b: 26). These efforts will bring about improvements in reducing the noise impact but they cannot be expected to replace land-use planning and zoning controls.

Speaking at a conference on aviation and the environment, Geoff Maynard, chairman of the UK's Royal Aeronautical Society operational sub-group believes that airspace reform is crucial if noise-reduction techniques more advanced than continuous descent approaches are to work (Wastnage 2005). The group is also studying other noise reduction methods including crosswind/tailwind landings, non-precision approaches to runways that avoid residential areas, noise abatement take-offs, noise preferential routeings, steeper approaches and displaced threshold landings (Wastnage 2005).

Recent increases in aircraft fuel prices have led to renewed airline interest in turboprop aircraft (Kingsley-Jones 2005a). Turboprop aircraft use less fuel than jet aircraft with a similar seating capacity, and on short routes the speed advantage of jets over turboprops is minor (Kingsley-Jones 2005b). The benefit of an increased proportion of turboprops is that they are quieter than jets, and this advantage is passed on to the airport's neighbours. However this benefit is relatively minor since jets are still preferred by airlines and passengers over medium distance to long flights due to their speed advantage so it is unlikely that jets will be replaced by turboprops on noise grounds alone.

Noise is made by aircraft engine run-ups and taxiing on the ground, during take-off and landing, and en-route between destinations. Take-off and landing operations when aircraft are being operated at high power settings and are close to the ground create the most noise problems. Bronzaft, Ahern, McGinn, O'Conner & Savino (1998) found that nearly 70% of residents who live within flight corridors reported themselves as being bothered by aircraft noise. Not all aircraft are noisy. Older jet aircraft, particularly those dating back to the 1970s are extremely noisy whilst new jets and turboprop aircraft are much quieter.

Noise from aircraft is very complex and comprises engine noise and airframe noise. Engine noise is the sum of noise produced by several engine components: fan, compressor, combustor, turbine and jet exhaust (Brennan et al. 1991). Airframe noise originates from the airframe itself as well as the undercarriage and undercarriage doors, wing flaps and slats when these are deployed on take-off and landing. The first jet engines were known as turbojets and were the noisiest engines. These were followed by low bypass ratio, and later high bypass ratio turbofan engines which are the quietest even though they produce much more thrust than early turbojet and low bypass ratio engines.

1.5.3 Airport noise or aircraft noise?

The terms airport noise and aircraft noise are often used interchangeably, leading to some confusion. The airport may be a source of noise nuisance when aircraft are on the ground maneuveuring or when engine testing takes place. However, the problem of aircraft noise extends much further into surrounding communities. In this study, the aircraft noise problem is assumed to affect neighbourhoods surrounding airports, where noise from aircraft in the air causes problems. The present study will therefore refer to aircraft noise.

1.5.4 Land-use and aircraft noise

The implementation of almost any transportation project brings with it a series of impacts or consequences that may be negative in nature, and in need of impact analysis and abatement considerations. Cohn & Harris (1987) assign the responsibility of dealing with the negative impact to environmental planners (also referred to as environmental engineers, analysts or specialists). Whilst environmental planners have a role to play, it is also up to legislators to enact comprehensive laws which environmental planners and town planners use to do their planning.

A land-use plan for property surrounding an airport boundary is an integral part of a comprehensive urban planning system and must be co-ordinated with the planning policies of the area in which the airport is located. Incompatibilities of an airport with its neighbours can include road traffic congestion, aircraft engine emissions, toxic chemicals and industrial waste, but the objections of the airport's neighbours to aircraft noise is the primary problem (Horonjeff & McKelvey 1983). Land-use planning must therefore take into account the projected extent of aircraft noise that will be generated by airport operations in the future. Where the land-use around the airport is underdeveloped, the projected aircraft noise contours must form the basis for establishing comprehensive land-use zones. Land-use zoning is not an effective method of controlling land-use in areas which are already built-up because such zoning is not retroactive. In those areas which are already built-up, citizens could be made aware of the noise impact in a process of providing transparent noise information.

Even though aircraft noise contours are available, municipal planning authorities having zoning powers may also not take effective action, thus rendering zoning ineffective (Horonjeff & McKelvey 1983). Height and hazard zoning is used to protect airport approaches from obstructions, and these zones may offer some protection against noise too, but they are limited to close proximity to the airport and it must be remembered that their primary intention is to provide space for safe flight operations.

The average energy noise contour calculation process is the traditional approach to noise planning and analysis around airports. The Federal Interagency Commission on Aviation Noise (2002) recommend the use of supplemental aircraft noise information (or supplemental metrics) to best determine noise impacts at specific noise-sensitive locations. Albee & Burn (2004) describe average energy contours as an exclusive process that defines some people who are located within a contour as having a significant noise problem whilst others located as close as next door, but who live outside the contour, are relegated to not having a problem. In the USA, a level of DNL 65dB is defined as the threshold of significant impact. Land-use planning zones are defined by aircraft noise pollution, and affected residents may qualify for funding to insulate their homes, or may even be bought out. Of the residents who live outside the zone, those that are the most sensitive to noise comprise the vocal opposition to these noise contours and noise zones.

Albee & Burn (2004) are of the opinion that given that most noise complaints come from persons residing outside the contour, it is clear that the general approach to conducting analyses of aircraft noise, and consequent planning, viz. average energy noise contours, needs improvement. This is similar to the view of the Australian Department of Transport who also consider average energy noise information inadequate (Commonwealth Department of Transport and Regional Services 2000).

Two phrases commonly used to describe the aircraft noise information which is additional to average energy noise metrics are ‘supplemental aircraft noise information’ and ‘transparent noise information’. Essentially the two describe the same intention, viz. the provision of additional information to that which is traditionally presented about aircraft noise. The use of the word ‘transparent’ implies that all types of noise information are made available in a transparent process. The use of the word ‘supplemental’ does convey that more information is made available, but when compared with the word ‘transparent’ it does not carry quite the same convincing message of openness. It is the intention of this study to encourage the use of both supplemental and transparent information, so the two terms will be used interchangeably.

1.6 AIRCRAFT NOISE AND LAND-USE CONTROLS IN SOUTH AFRICA: THE REGULATORY FRAMEWORK FOR NOISE

A regulatory framework which deals with broad environmental issues per se, and which proceeds down to the specific level of noise and aircraft noise, has been constructed in South Africa. This framework is discussed in this section.

1.6.1 Noise and the Constitution

The right to health and well-being is provided for in the Bill of Rights contained in Chapter 2 of the Constitution of South Africa (South Africa 1996). The right to an environment that is conducive to well-being is apt in the context of noise pollution (Glazewski 2000). Schedule 4, Part A of the Constitution includes the 'environment' as a functional area of concurrent national and provincial legislative competence while Schedule 5 Part B specifically includes noise pollution as a provincial function provided that the local authority has the capacity to carry out this function (South Africa 1996).

The Constitution contributes to the mitigation of noise by recognising that noise is a problem. In broad terms, it provides for a regulatory structure to deal with noise, but does not go into specific details. This is left up to national, provincial and local regulations which will be discussed in the next section.

1.6.2 Noise control regulations

The wide definition of the 'environment' in the Environment Conservation Act and the National Environmental Management Act means that "… noise pollution is also included under the purview of both of these acts" (Glazewski 2000: 748). It is clear from the paragraph above that noise pollution control is primarily a provincial responsibility. Three provinces which have passed their own noise control regulations are the Free State, Gauteng and the Western Cape (Glazewski 2000). Although these are provincial laws, they are "… to be applied by local authorities…" (Glazewski 2000: 752).

In Gauteng, the Department of Agriculture, Conservation and Environment has published a service delivery charter in which sustainable development in Gauteng is to be facilitated by "… ensuring sustainable land-uses … and land-use patterns" (Gauteng Department of Agriculture, Conservation and Environment. s.d. no page). The service delivery charter includes reference to noise control regulations. These regulations are published in order to "… provide a uniform minimum standard for noise regulation" and "create new mechanisms for effective enforcement in neighbourhoods" (Gauteng Department of Agriculture, Conservation and Environment 1999 no page). However, only brief mention is made of aircraft noise in that a local authority may designate a controlled area where "… air traffic noise in the vicinity of an airfield … exceeds 65dBA" (Gauteng Department of Agriculture, Conservation and Environment 1999: 1). The regulations refer to the previous code of practice for aircraft noise calculation (SABS 0117-1974) in which it is stated that for residential areas "… the total noisiness index … should not exceed 65 for residential areas" (South African Bureau of Standards 1974: 5). In 2003 a new standard was introduced (not referred to as a code of practice any more), but the Gauteng noise control regulations have not yet been updated to reflect this. This has led to confusion in the province where airport developers and town planners have, in some instances, used old regulations to justify their developments, whilst in others new standards are referred to.

1.6.3 Aircraft noise and environmental policy

An aircraft noise and environment policy has been in a process of development since 1999. The most recent release (16 March 2005) is a third draft of the white paper on national civil aviation policy which contains (in Chapter 6), draft policy on aircraft operations and the environment (National Department of Transport 2005). Section 6.9.1 of the white paper recognizes the importance of noise contours for the long-term planning of land-uses around airports. The proposed policy specifies that the calculation of noise contours for an airport must be in accordance with SANS 10117-2003.

1.6.4 Noise standards: SABS 0117-1974, SANS 10117:2003 & SANS 10103:2003

The SABS standard SABS 0117-1974, published in 1974, covered the calculation of noise contours for an airport for the purpose of zoning of land to prevent disturbance in future residential areas around the airport. This code of practice was replaced in 2003 by the SANS 10103:2003 standard (dealing amongst others with land-use) and by SANS 10117:2003 which specifies the calculation method for predicting aircraft noise around airports. Importantly, none of the policies, standards or regulations refer to supplemental or transparent noise information. In each instance, the noise calculations refer to average energy aircraft noise representations.

1.7 RESEARCH METHODOLOGY USED FOR INVESTIGATING AIRCRAFT NOISE DISTURBANCE

Disturbance from aircraft noise is well documented, the seminal work by Theodore Schultz in which he devised a dose-response relationship based on a number of other surveys being an oft-quoted example (Schultz 1978). Noise from aircraft can adversely affect people living near airports in many ways and concern that night-time noise is detrimental to public welfare is understandable. The evening and night-time is when people are usually at home, relaxing, watching television or listening to music, sleeping, studying and so on. Using the World Health Organisation (1946: 2) definition of health, namely '… a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity', it is clear that night-time environmental noise including aircraft noise adversely affects health by causing chronic subjective reactions (Porter, Kershaw & Ollerhead 2000).

In South Africa aircraft noise has received some attention although not very much. Whilst van der Linde (2003) found no noise related papers published by geographers in the period 1996-2001, Goldschagg (2002) traces the development of aircraft noise agreements and their consequences for those living near airports. Van der Merwe & Von Holdt (2005) and Van der Merwe & Von Holdt (2006) have found that while aircraft noise is often deemed to be of little importance, steadily increasing air traffic requires the demarcation of noise-controlled areas around airports to manage the environmental nuisance. In the present study the goal will be to help fill this gap by obtaining the opinions about airport noise that people living in the vicinity of the airport have at those times when they are most likely to be disturbed, i.e. in the evening and at night when they are at home. A survey was designed to investigate people's perception of aircraft noise when they are most likely to be at home in the evening and at night. It was important for people to be at home so that their geographical location could be established. A time period of 18:00 to 06:00 was selected. The survey questions were selected to investigate the nature of the disturbance from aircraft noise. These included whether people felt annoyed, and if interference occurred with activities including sleep, television viewing, talking on the telephone and working or studying. Furthermore, it probed whether people would consider moving away because of aircraft noise. A questionnaire survey was undertaken and participants were asked to respond to questions about aircraft noise during the week of 16-22 October 2004 (Appendix A). At the end of the week, respondents were required to return the questionnaire in a pre-addressed, stamped envelope.

At the end of the survey week the air traffic control flight logsheets for that week were obtained. From the flight information on the logsheets, five sets of noise contours were calculated:

- A 24-hour average energy contour (according to the SANS 10117 method)
- A 12-hour (from 18:00 to 06:00) night-time L_{Aeq} average energy aircraft noise contour;
- A 12-hour (from 18:00 to 06:00) number of events above 60dBA (N60) contour;
- A 12-hour (from 18:00 to 06:00) number of events above 70dBA (N70) contour;
- A 12-hour (from 18:00 to 06:00) number of events above 80dBA (N80) contour.

The noise contours of the first two types represent lines of equal noise exposure. The outermost (quietest) contour that was mapped is 55dBA, and the contours increase with increasing noise level in increments of 5dBA closer to the airport.

The latter three noise contours are representations of the number of aircraft noise events exceeding 60-, 70- and 80dBA for the specified time period of 18:00 to 06:00. The outermost contour that was mapped represents less than 10 events of the specified level, and the number of events increases with increasing noise level closer to the airport to 10-20 events, 21-50 events, and more than 50 events to form four ‘Number of Events’ noise zones.

The geographical locations of the survey respondents were captured into a GIS, and the five noise contour sets overlaid. The responses of the respondents within each of the five sets of noise zones respectively were analysed. The survey responses were correlated with noise disturbance using standard descriptive statistics.

1.8 DEMARCATION OF STUDY AREA AND TARGET RESPONDENT POPULATION

Ekurhuleni Metropolitan Municipality recognise the importance of dealing with airport noise “JIA (now ORTIA) is causing noise pollution in the surrounding residential areas especially Kempton Park… ” (Ekurhuleni Metropolitan Municipality 2003a: 41). This quote provided some insight on the area of study. Aircraft noise disturbance is limited to the vicinity of flight corridors near airports. To demarcate the study area and target population, air traffic flight routes, previously produced noise contours, and land-use maps were consulted.

1.8.1 Air traffic flight routes

The air traffic control authorities produce standard arrival and departure routes for busy airports primarily to ensure safe operation of aircraft. These are known as Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs). All pilots are expected to be familiar with these routes and comply with them unless otherwise instructed. The actual routes flown can vary for a number of reasons; viz. weather, aircraft type, pilot technique and air traffic control are common. The SIDs and STARs were carefully studied. A visit to the Air Traffic Control Centre of the airport was undertaken to familiarise the researcher with air traffic control routes at ORTIA. Flight paths of arriving and departing aircraft were studied on the radar screens in order to determine where the aircraft operate, and advice sought from the air traffic controllers who control flights into and out of the airport on a daily basis.

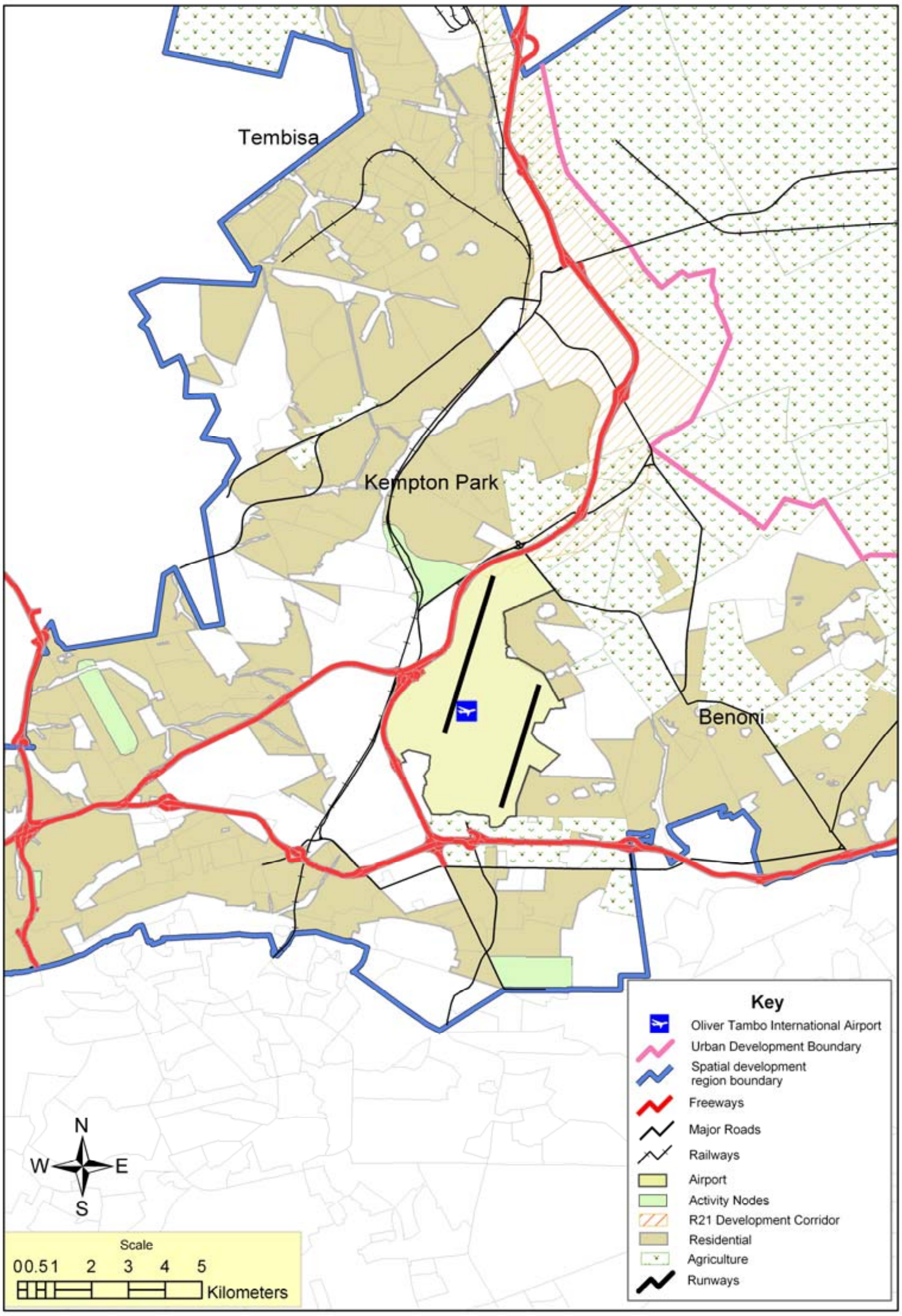
1.8.2 Previously produced noise contours

In 2001, during the review of the SABS standard for aircraft noise calculations, three sets of aircraft noise contours using an identical set of aircraft operational data but applying different night-time periods and associated weightings were produced (Goldschagg 2001). The three contours produced for this review of the SABS standards in 2001 were overlaid onto a land-use map of the neighbourhoods around the airport. The shape and spatial extent of the contours was studied in order to gain further understanding of the extent of the noise.

From the flight routes, radar screens, and noise contours for 2001, it was possible to determine which areas were most likely to be overflown by aircraft, and consequently affected by noise from these aircraft.

1.8.3 Land-use maps

The 1:50 000 scale topographical series maps (2527DD, 2528CC, 2528CD, 2628AA, 2628AB and 2628AC), and electronic maps sourced from the local authority were scrutinised to determine where people around the airport live. Kempton Park and Tembisa to the north of the airport contain many residential dwellings (Figure 1.1) and these municipal districts formed the study area.



Source: compiled by author

Figure 1.1: Location of ORTIA and its surrounding land-uses

1.9 REPORT STRUCTURE AND SEQUENCE

The structure of the research is outlined in Figure 1.2.

Chapter 2 is a review of the literature. This will include average energy aircraft noise metrics, land-use planning and supplemental aircraft noise information. Chapter 3 documents the design and methodology followed during the collection of aircraft operational data and calculation of the aircraft noise contours, and the design and administration of the survey. The survey results according to the average energy noise descriptor are displayed and interpreted in Chapter 4. In Chapter 5, the survey results are interpreted according to the supplemental aircraft noise information descriptors, these being the 12-hour evening and night L_{Aeq}, and number of events above 60, 70 and 80dB. Chapter 6 develops the results from Chapters 4 and 5 by proposing an inclusive aircraft noise planning framework. Chapter 7 contains conclusions and recommendations of this study.

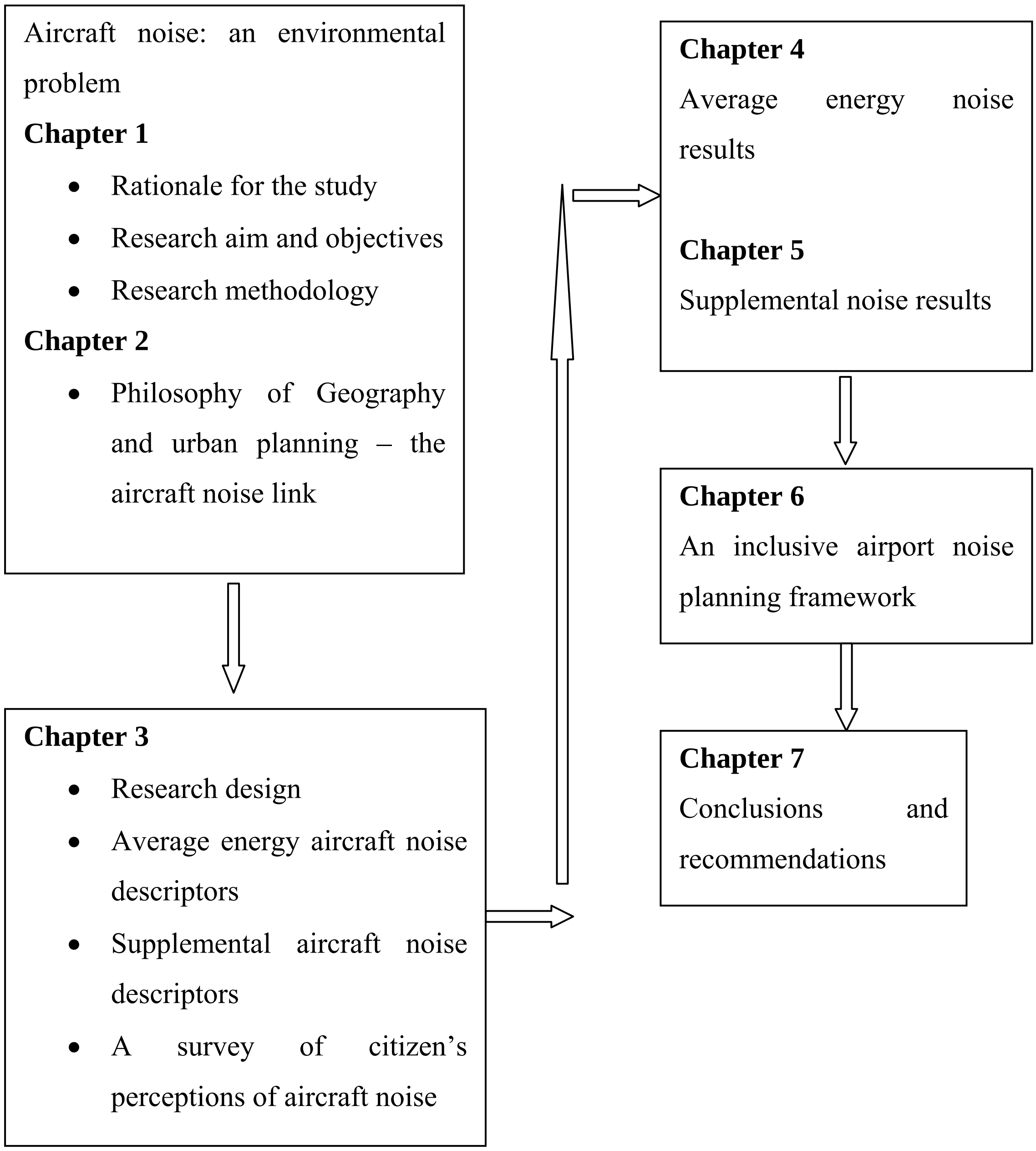


Figure 1.2: Research design and process

CHAPTER 2: AIRCRAFT NOISE AND LAND-USE PLANNING: THE LINK WITH GEOGRAPHY

In Chapter 1, the problem of noise and aircraft noise and consequently the need to conduct suitable land-use planning was discussed. ‘Traditional’ noise contours were discussed. Providing supplemental aircraft noise information is proposed as an approach that can foster and reinforce town planning. The possibility of this being realised is a fundamental focus of this study. Chapter 1 also pointed out that the research methodology draws strongly on realism and pragmatism. These approaches necessitate four fields of research namely: land-use planning, socio-psychoacoustics, air traffic control and the aviation sphere of activity. In this chapter, the links between the foregoing and geography are explored.

2.1 INTRODUCTION: DEMARCATING THE LITERATURE COVERED

The literature review in this chapter is organised around the following key constructs:

- Spatial data analysis
- Noise – physical effects; physiological effects; effects on communication and productivity; psychological effects
- Airport noise disturbance
- Land use regulatory framework
- Land-use planning in the vicinity of airports based on L_{Rdn} noise contours
- Supplemental aircraft noise information.

2.2 SPATIAL DATA ANALYSIS – PLACE OF THE RESEARCH IN THE REALM OF GEOGRAPHY

A hundred years ago, the geographer’s job was the ‘grand survey’ – mapping the landscape from a balloon or a hilltop to guide subsequent travellers through it (Holt-Jensen 1999). Buttimer (1993: 63) reports on the Victorian image of the geographer as “… master teacher capable of integrating insights from a great variety of other disciplines…”. There is some truth in the ‘integrating insights’ phrase in this statement in the present study where acoustics, aviation, town planning and socio-psychoacoustics are integrated. Geography pays great attention to the environment

(Porteous 1977) which in the present study requires an interface between the subdisciplines of acoustics, town planning and aviation.

Buttimer (1993) speaks of the recovery of the human subject – the recognition of human agency as an integral part of the lived world. Human agency is communicated as the inner thought and feelings of people. The negative impact of aircraft noise on people is difficult to quantify since responses are subjective. People who are negatively affected by the noise from aircraft have feelings which should be acknowledged and attended to. The subjectivity is difficult to quantify scientifically on an individual basis yet when individual responses are aggregated to a community level, some common response patterns emerge.

Scientifically based knowledge can be described as the result of a search for new insight and understanding. Description of phenomena, prediction, causality and explanation are all closely linked (Smit 1995) and geography is ideally suited to consider these four aspects. Firstly, the phenomena to be studied are aircraft flights, town planning, air traffic control, socio-psychoacoustics; secondly, the noise impact from aircraft flights can be predicted through scientific calculations; thirdly the causal link between aircraft noise and community response can be established; and fourthly, explanation can be made regarding two aspects of aircraft noise – in the short-term the choices residents make to live in a noise affected area and in the longer term, decisions land-use planners have to make about planning. Essentially, the aircraft noise problem can be studied from a spatial data analysis viewpoint. In a geographical spatial data analysis context, all events have space and time co-ordinates attached to them (Haining 2003). In the present study, the impact of aircraft noise 'taking' space in a time-frame which people find disruptive (evening and night) will be examined. In many areas of experimental science, the exact spatial co-ordinates do not usually need to enter the database as such information is not of any material importance in analysing the outcomes. However, spatial co-ordinates are important in the present study, and will therefore be included. This is because the location of the respondents and their responses is important in analysing their response to noise according to noise zone.

The present research lies within the social and environmental sciences which are largely observational and not experimental, so the results are taken as found (Hainig 2003). The researcher is not able to experiment with the levels of the explanatory variables namely aircraft noise levels. Spatial data analysis has a role to play in supporting the search for scientific explanation (aircraft noise annoyance and interference with activities), and more general problem solving (land-use planning) (Haining 2003).

In the rest of this section, generic issues of place, context and space in scientific explanation will be explored to reinforce the links with geography.

2.2.1 Location as place and context

Location enters into scientific explanation when geographically defined areas are conceptualised as collections of a particular mix of attribute values. Airport noise analysis is the study of spatially aggregated data where the object of study is an individual member of a household as the spatial unit. This study will focus on individual-level characteristics. Area-level characteristics in the form of the township response and suburb response which were also observed to have an impact will also be analysed.

Explaining spatial variation needs to disentangle 'compositional' and 'contextual' influences. Geographical variations in response to aircraft noise may be due to differences between areas in the resident population in terms of say distance from the airport and types of aircraft operating (the *compositional* effect). Variation may also be due to differences between areas in terms of exposure to the noise factor that may have a direct or indirect effect on causing annoyance and interference (the *contextual* effect) (Haining 2003).

In this study, the contextual properties of the geographical areas are important. The variation of noise zones across the study area may be explained in terms of the numbers of aircraft movements, aircraft types, times of flights, flight paths used, meteorological conditions and type of noise descriptor (the compositional effect). The contextual effect may operate at several scales or levels, for example neighbourhood quality. Neighbourhoods influence behaviour, attitudes, values and opportunities (Brooks-Gunn, Duncan, Klebanov & Sealand 1993). For this reason, the analysis will separate the respondents into a township group and a suburb group.

The introduction of ‘place’ raises the problem of how to handle scale effects. ‘Place’ can refer to objects of varying sizes. In this study, ‘place’ is regarded as the house where the respondent lives.

2.2.2 Location and spatial relationships

The second way location enters into scientific explanation is through the ‘space’ view (Haining 2003). This emphasises how objects are positioned with respect to one another and how this relative positioning may enter into explaining variability, for example, where the residential areas are positioned in relation to the airport and, more importantly, the flight routes around the airport.

Distance becomes part of a scientific explanation when attribute variability (annoyance and disturbance) across a set of areas is shown to be a consequence of how far areas are from a particular region that possesses what may be a critical level of some causal factor. For example, how close are houses to the airport and flight paths? The closer they are, the greater the noise level that can be expected, especially if they are in the flight paths.

A gradient is a local property of space, for example how similar or how different two neighbouring areas are in terms of variable characteristics, in this case aircraft noise. Aircraft noise level at a location depends on how many aircraft fly over, the type of aircraft, their height above, or distance from the location, and the engine power setting. The further from the airport and the flight path, the less the noise from aircraft, and the lower the expected annoyance and interference will be. The research will investigate whether a noise annoyance and disturbance gradient exists.

2.2.3 Spatial processes

Certain spatial processes operate in geographic space. Haining (2003) discusses four generic types: diffusion, interaction, exchange and transfer, and dispersal processes. The first two and last are fitting, and given more attention here.

A *diffusion* process is interpreted here to mean where some attribute – in this case diffusion of aircraft noise – is taken up by a population, and at any point in time it is possible to say which areas have the attribute, and how much of it, and which do not. The mechanism by which the attribute affects the population depends on the flight characteristics (aircraft type, frequency, height), and the noise descriptor. The noise descriptor will be revisited later.

An *interaction* process is one in which outcomes at one location influence, and are influenced by, outcomes at other locations. For example, the ICAO phase-out of noisy aircraft in Europe and the USA, led to the purchase of many of these aircraft in South Africa. Consequently flight frequencies increased, and noise levels increased at locations near flight paths around the airport. A growing economy leads to an increased demand for business travel. A change in government in South Africa to a democracy in 1994 led to a lifting of sanctions and an increase in the number of foreign airlines operating to South Africa as a result of increased passenger demand.

In a diffusion process, the attribute spreads through the population. The final type of process is a *dispersal* process, where two types of dispersal may be considered. Firstly, the population who are most annoyed by aircraft noise may move away to be replaced by others who are not aware of the noise problem or who are not as annoyed. Secondly, the flights may be dispersed in such a way that the noise is less intense but is diffused over a larger area.

2.2.4 Defining spatial sub-disciplines

Cloke, Cook, Crang, Goodwin, Painter & Philo (2004) argue that using statistics to perform descriptive functions is regarded as the foundation level of analysis to be built on by strategies of hypothesis testing so as to infer either difference or association. This argument will be followed in this research where it will be attempted to establish that noise is a problem (descriptive) and there is a difference in the survey responses according to aircraft noise zones.

Heuristic research is often linked to psychotherapy, but it is also a process of continual questioning and checking to ensure explication of one's experiences (Moustakas 1990). The survey conducted in this research lends itself partially to this process. Respondents were expected to communicate their own experiences (of aircraft noise) which required them to examine their feelings. Heightened awareness of aircraft noise may occur at night when respondents have an expectation for relative quiet when they want to watch TV undisturbed, or 'absolute quiet' when they sleep.

The quality of the environment in a given urban place will influence the quality of life for its residents. Goodall (2000) contends that three factors have a particular bearing on environmental quality: (i) public health; (ii) provision of an efficient urban structure; and (iii) creation of an environment which maximises people's comfort and enjoyment of living. Airport noise is at least dealt with by (i) and (iii) for residents living near airports, whilst the airport itself may be regarded as contributing to efficient urban structure.

Present land-use planning around an airport is a legacy of past and present phases of land-use development. Quality of the urban environment is reflected in the juxtaposition of land-uses (Goodall 2000) so that past and present built forms are not always good neighbours. This is reflected in the relative location of residential areas located under or close to airport flight paths. Residents are heard to say that they have lived in the area long before the airport became so busy. Airport owners in turn respond that people should not buy houses which are close to the airport.

Aircraft noise pollution arises from the provision of transport services. Urban areas are concentrated centres where aircraft arrive and depart, and where there are dense concentrations of population. Many current urban activities date back to times when urban environmental quality was accorded a lower priority than today. Technical capability to reduce aircraft noise, measure it, and predict it was limited, and the legislative framework did not exist. Whilst advances have been made in the technical aspects of noise reduction, legislation has not kept up, or is out of date or confusing.

Planning implies that future developments and proposed activities are environmentally friendly by requiring appropriate environmental impact assessments to be done before granting permission to succeed. However, in the case of an airport, activities continue. Usually, planners have an opportunity to bring polluters into the net when they seek in some way to redevelop or increase the use intensity of their sites.

Goodall (2000) stresses the need for an environmental database to be produced, to identify the features of the problem and allow the environmental performance of individual polluters to be determined. The Airports Council International (ACI) has proposed an aircraft noise rating index (Airports Council International 2005). Recognising that airport noise is the single major cause of community opposition to airport capacity development to meet future traffic growth, the ACI developed this tool to assist airports with rating all aircraft which operate into an airport, on the basis of the certificated noise levels relative to Chapter 3 standards. The index gives information about the status of an aircraft relative to the state of the art in noise reduction technology.

2.3 NOISE: KEY CONCEPTS AND NEGATIVE EFFECTS

Acoustics, sound and noise comprise a vast field of study. Some basics are imparted in the following sections drawn from Fuggle & Rabie (1999) and Bristow, Wardman, Heaver, Murphy, Hulme, Dimitriu, Plachinski, Hullah & Eliff (2003).

2.3.1 Noise concepts

2.3.1.1 Sound

Sound may be loosely described as that which we can hear. Fluctuations in the static air pressure that surrounds us are perceived by our ears as sound. Loudness is related to the amplitude of these fluctuations. In general, the loudness of the sound decreases as the distance from the sound source increases. In an outdoors environment under certain atmospheric conditions (eg a temperature inversion) loudness can temporarily increase with distance.

2.3.1.2 Noise

Noise is a particular category of sound which is undesirable. The factors which cause a sound to be undesirable are physical, physiological, or psychological in nature or those that effect communication and productivity.

Physical damage to the ear caused by aircraft noise is rare and will not be treated further here. The most important physiological effect is loss of hearing acuity caused by repeated exposure to high noise levels, primarily in the workplace. This is an occupational hazard, not an environmental concern and will not be discussed further here.

Even at levels below those which cause hearing damage, aircraft noise can be annoying, and cause interference with communication such as television viewing, radio listening and telephone conversations. Noise at the lower end of the severity scale is the most significant from an environmental point of view. Noise causes interference with activities and annoyance which leads to negative community reactions (Johnston 1992). Aircraft noise can propagate over considerable distances and consequently affect a large population. A single noisy aeroplane can awaken an entire suburb in the early hours of the morning.

2.3.1.3 Measurement of noise

The intensity of sound is usually expressed in decibels (dB). The range of intensities encountered is very great, so the intensity level is expressed as 20 times the logarithm of the ratio of the sound pressure of a particular sound (P) to a standard reference pressure (P_0). By using decibels as a unit of measure, the large range of sound intensities can be compressed into a range from 0 to 150 decibels. A jet aircraft can generate a noise level of over 100 dB. The average noise level in a residential area varies from 55 to 65 dB.

The human ear is not equally sensitive to all audible frequencies. It is most sensitive at medium frequencies of about 3-4kHz. Noise measuring instruments are adapted at different frequencies so that they react in a similar fashion to the human ear. This adaptation is known as frequency weighting, and is referred to as the A-weighting. The term commonly used to denote sound measurements employing the A-weighting is dBA (Horonjeff & McKelvey 1983).

Most noises (including aircraft noise) vary in loudness over time. It is therefore essential that noise measurements and calculations perform some averaging function over a period of time. To this end, the L_{Aeq} descriptor has achieved widespread usage. L_{Aeq} is a long-term average taken over the entire measurement period which may for example be a 12 hour night period, a day, or even year. Because of the possible variations of the time that L_{Aeq} can be measured over, it is vital that the user articulate this in any usage.

2.3.1.4 Assessment of noise

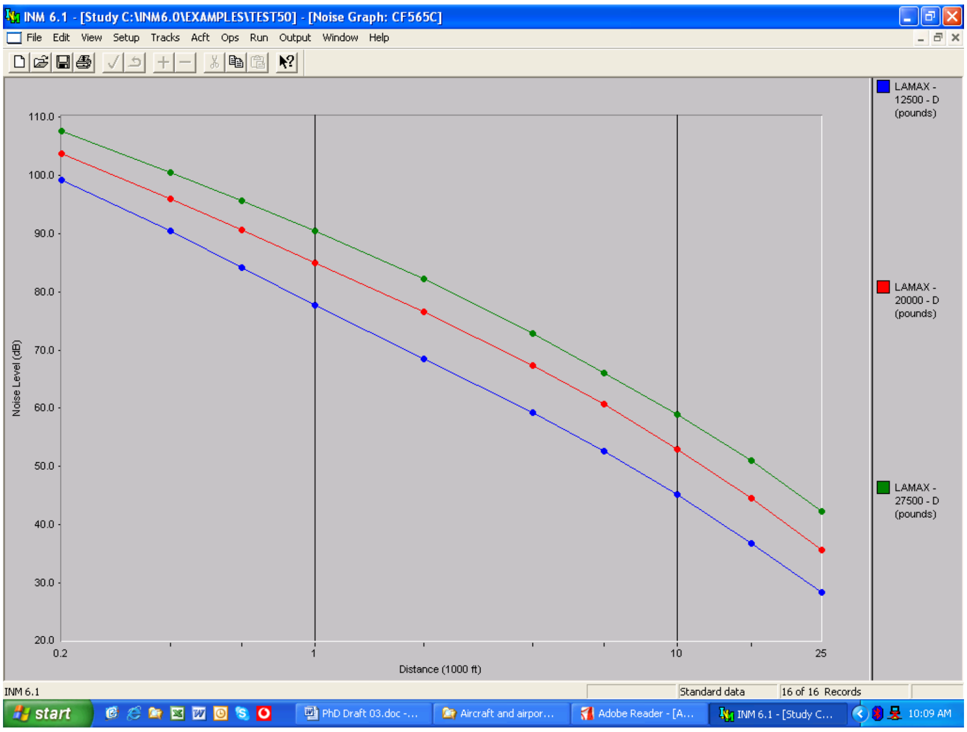
Aircraft noise is a necessary by-product of the operation of this type of transport vehicle. Aircraft produce noise from their engines, and from the flow of air over their wings, fuselage and undercarriage. Consequently, noise around airports is a troublesome problem for the aircraft operators, airport operator, local authorities, and residents (Ashford, Martin Stanton & Moore 1984).

Noise has been defined as unwanted sound and there is a strong element of subjectivity in its measurement. Intensity of sound alone is not a suitable measure. The time the sound is heard is another factor that strongly affects the reactions of people. This creates difficulties when attempting to assess the impact of a given noise, and when setting limits (Horonjeff & McKelvey 1983).

Another important factor in the evaluation of sound is the frequency, described as the vibration of a sound source expressed in cycles per second. An object which vibrates fast has a high number of cycles per second and a high frequency, measured in hertz. The human ear can detect sounds over a wide frequency range, from about 16 hertz to about 16 kilohertz.

The overall sound pressure level represents an equal weighting of the frequencies generated by a particular sound. Unless a sound is a pure tone it is made up of a range of frequencies. A variety of frequency-weighting networks has been devised, the most commonly used one being the A-weighting since it has been found to account for the human ear's perception of sound (Horonjeff & McKelvey 1983). Although the D-weighting (which weights higher frequencies more) has also been proposed for the measurement of aircraft noise (Smith, Peters & Owen 1996), the A-weighting remains in common use because it gives greater weight to frequencies which are more annoying to the listener.

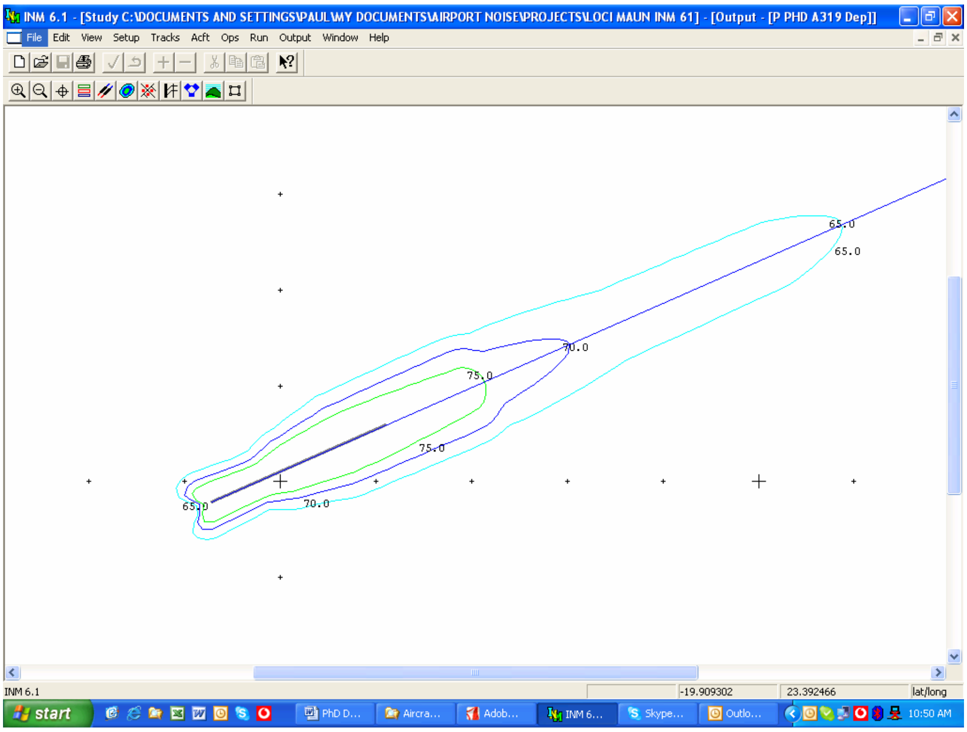
On the basis of extensive measurements of noise made on the ground during aircraft flyovers, the relationship between the maximum noise level observed on the ground and the distance to the aircraft can be determined. This relationship can be expressed as a graph (Figure 2.1) which is extracted from the Integrated Noise Model.



Source: Federal Aviation Administration (2003), compiled by author

Figure 2.1: Relationship between distance and noise level for an aircraft on departure with three different thrust settings.

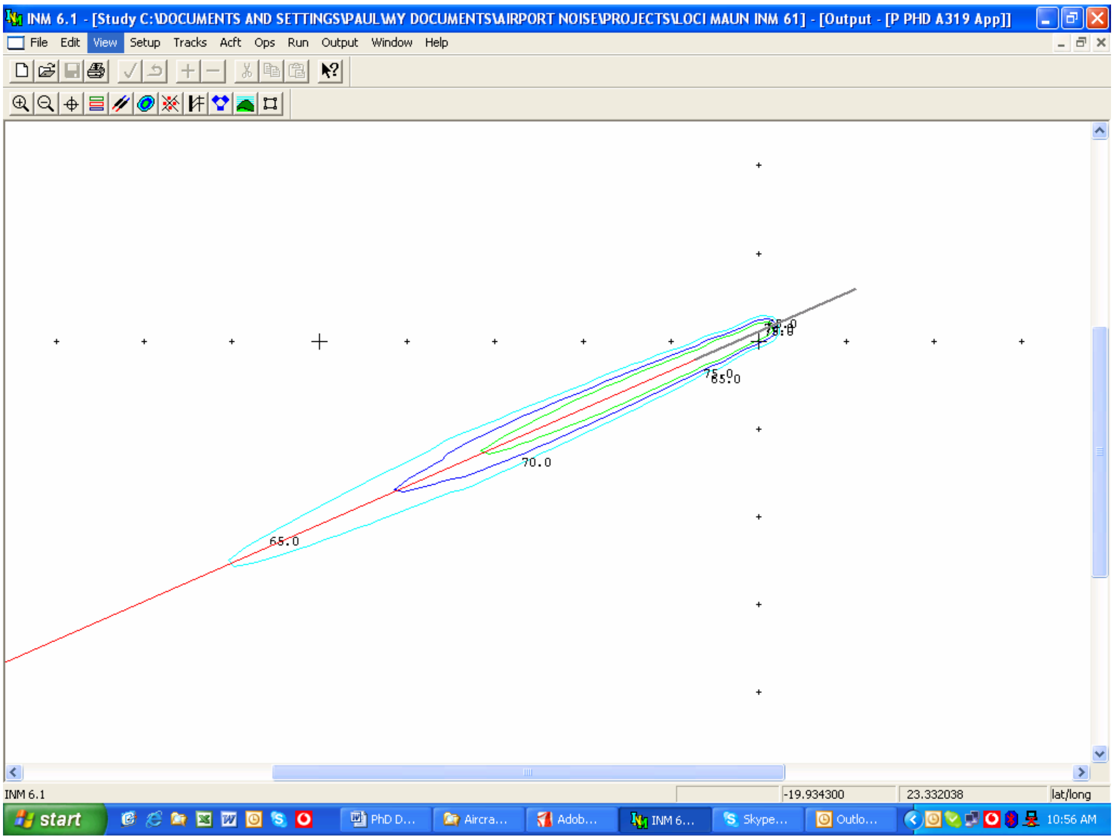
Clearly, as the distance between aircraft and observer increases, the noise level on the ground decreases. By using this graph, the noise level of an aircraft taking off can be determined at any distance from the aircraft. The same may be done for landings. A set of noise contours representing the maximum noise levels on the ground can also be constructed (see Figures 2.2 and 2.3).



Source: Federal Aviation Administration (2003), compiled by author

Figure 2.2: Noise contour of a departing aircraft.

Note that the noise contours in Figures 2.2 and 2.3 represent the sound levels generated by a single departure and arrival respectively of one type of aircraft.



Source: Federal Aviation Administration (2003), compiled by author

Figure 2.3: Noise contour of an arriving aircraft

In order to determine the response of the community to aircraft noise, the cumulative effects of the noise created by the arrivals and departures of many aircraft must be considered.

Investigations of aircraft noise disturbance have shown that the impact on neighbourhoods is not only caused by single events, but also by the duration and number of events occurring during the day and night (Horonjeff & McKelvey 1983; Fujii, Soeta & Ando 2001). A number of methods of combining the noise levels from single events into measures of cumulative noise exposure, or average energy have been developed. In South Africa, the day night rating level (L_{Rdn}) is prescribed by Standards South Africa (2003). The L_{Rdn}, although differing in technical detail from other well-known methods, for example the DNL (USA), NNI and Leq (UK) and TNL (Total noise load, Holland) is conceptually very similar. Noise can also be described as the number of events, either all the events or the events that exceed a certain level, and the noise value of these events, for example the maximum value (Rylander & Björkman 1997).

Awareness has grown that hearing damage is a limited aspect of the harmfulness of noise and that continual noise (average, peak, number of events) is likely to bring about psychological discomfort and somatic disorders. Background noise in urban areas is rising, increasing annoyance and so creating wide-ranging urban areas which, although not intensely noisy, are placed where the stock of silence is being eroded (Burns 1968; Ashford, Stanton & Moore 1984; Organisation for Economic Co-operation and Development 1986; Nero & Black 2000).

2.3.2 Negative effects of noise

2.3.2.1 Physiological effects

When people are exposed to sounds, an impulse is registered in the ear, and the subsequent signal in the auditory nerve is interpreted in the central nervous system. The neurophysiological reaction mechanism is such that the sounds most noticed are those which exceed the background level. Sounds which are excessively loud, which have a tone, and tend to increase and decrease suddenly, and so on, are often referred to as noise. Noise studies usually consider a number of events over a given time period, and are traditionally expressed as an average value. If a sound is loud enough, or if the recipient is exposed to it for long enough, permanent hearing damage may occur. Noise may also cause cardiovascular and digestive diseases (Organisation for Economic Co-operation and Development 1986; Quehl & Basner 2006).

2.3.2.2 Interference with communication

Speech, whether direct, or by telephone, can be interfered with by noise. Researchers have shown that noise is an inconvenience and can disrupt work or leisure activities. With noise at low intensities it is possible for people to talk louder or move closer in order to be heard. As noise increases, it gradually masks conversation until even shouted speech cannot be discerned (Smith, Peters & Owen 1996).

Experimental psychologists have for many years been conducting research on the effect of noise in the workplace. Some noise may be helpful, for example the noise a machine makes may be helpful to an operator, but annoying to somebody else. Music at a party may be enjoyable, but not when a researcher is trying to write a report. The point is that the way a sound is perceived depends on more than just its intensity or frequency (Burns 1968; Smith, Peters & Owen 1996; Zaporozhets & Tokarev 1998).

2.3.2.3 Psychological annoyance

This term is given to the annoyance that is the subjective expression that people have about noise. The use of the annoyance concept encounters a number of difficulties of correlating acoustical indices with the level of human response owing to the subjectivity of responses. Despite this, surveys show a high degree of consistency in expressing annoyance due to noise, with an increasingly high percentage of individuals who express annoyance as noise increases.

2.4 AIRPORT NOISE DISTURBANCE.

By definition, noise is unwanted sound. In tracing the development of thinking on airport noise, it is important to recognise that efforts to predict the annoyance of noise exposure on individuals and communities began as early as the 1930s, in the United States (Fidell 1990). More recently, Connor (1968) conducted research for the National Aeronautical and Space Administration (NASA) to investigate aircraft noise exposure. In a study funded by NASA at four airports, Hazard (1971) examined the relationship between public annoyance with aircraft noise and various noise exposure variables. That study’s aim was to investigate the relationship between public annoyance with aircraft noise, objective measures of the noise itself, and social or psychological conditions which affect the noise-annoyance relationship, Three key findings which are important for the present study, namely noise from aircraft does create annoyance; psychological adjustment ‘possibly’ occurs in individuals living immediately adjacent to or under flight paths at the ends of runways; and persons living in relatively quiet neighbourhoods several kilometres from an airport experience annoyance reactions to aircraft noise. These findings, made over three decades ago, point to the fact that aircraft noise disturbance occurs some distance from an airport.

Theodore Schultz's seminal paper (1978) compared the conclusions of 18 social surveys on annoyance due to noise. He concluded that the results of 11 of the surveys show a remarkable consistency and proposed that the average of these curves "… is the best currently available relationship for predicting community annoyance due to transportation noise of all kinds" (Schultz 1978: 377). Known as the Schultz curve, it has been widely used to determine annoyance responses, despite criticism about the generalisations in the methods employed (Kryter 1982; Hall 1984).

Hall (1984) reported that various studies of aircraft noise annoyance and interference at the same location (Heathrow) have produced differing results but they agree that the aircraft annoyance function is greater than that for road traffic.

Burns (1968) reports that there is a wide range of individual responses to noise from aircraft operations in the vicinity of airports. Noise levels that are extremely annoying and disturbing to some individuals cause little disturbance to others. The reasons for the differences are complex and difficult to extract. Research has indicated that unlike individual responses, the response of the community is more predictable because of the large number of individuals involved. Below exposure levels of 55DNL (similar to 55 L_{Rdn} in South Africa), the percentage of affected individuals who are highly annoyed by aircraft noise is low. Above 80DNL, over half the community is annoyed.

Downing (2004) discusses simulation based modelling as opposed to average energy modelling. Since computational capabilities have increased, it is now possible to simulate noise exposure on a personal computer. Such simulation modelling can be linked to supplemental noise.

The principal concerns of geographers with respect to annoyance from aircraft noise, involves research on land-use planning in the vicinity of airports which, in turn, is based on the sociological domain of testing people's reactions to aircraft noise. Researching the expectations of an airport's neighbours and how they perceive aircraft noise, will allow the development of supplemental noise information, and will also cater for the need of airport neighbours to visualise the noise they are likely to be exposed to, and will decide whether the noise levels will be acceptable to them. Great disappointment, leading to annoyance, can be experienced by residents when their expectations of a quiet neighbourhood, a peaceful night's sleep, and uninterrupted TV viewing and telephone conversations are not met.

2.5 ENVIRONMENTAL ETHICS

A recognised field of study within philosophy is environmental ethics – usually referring to the threats to nature posed by humans. Threats by humans to humans are also included in environmental ethics (Attfield 2003, Light & Rolston 2003). Public goods (in this case airports) create accountability problems because their disrupters (aircraft) are not the victims of the disruption they cause (Scherer 2003). Aircraft noise, for example creates annoyance and interferes with the activities of communities on the ground. However, the airport itself does not create very much noise for its neighbours, if any at all. It is the clients of the airport who are mostly responsible for the problem.

2.6 JOHANNESBURG: WORLD CITY AND OR TAMBO INTERNATIONAL AIRPORT AS A GLOBAL TRANSPORT NODE

Cities provide a variety of services including government, transportation, communication, education, trade, manufacturing, wholesaling, business services, retailing, and entertainment. The hinterland surrounding a city also benefits from these services. A primate city is one which concentrates a high degree of the entire national population or of national political, intellectual or economic life. Greater Johannesburg, can be regarded as the primate city of South Africa with its influence spreading even further into southern Africa.

South Africa is widely regarded as a developing country, and as economic development takes place so urbanisation is set to continue, and Johannesburg will be part of this growth. The discovery of gold resources led to the sustained growth of

Johannesburg in the past. Whilst the importance of gold to Johannesburg has declined, the manufacturing industry and tertiary services such as the financial sector have become more important. Abundant energy supplies at comparatively low cost have also enhanced growth so that Johannesburg is of primary importance to South Africa's economy.

Structure and location are fundamental to geographers in explaining a region's prosperity. Structure and location are enhanced by access in the form of communication in this case, transportation. The economic importance of Johannesburg has been enhanced by, and has enhanced good air transport access which has played its part in Johannesburg's growth.

Airports form an important component of the transportation network. ORTIA is South Africa's busiest airport in terms of aircraft movements, passengers and freight handled. The airport operator is responsible for providing a world-class service to the aviation industry and as such is determined that ORTIA be able to accommodate passenger growth and continue to act as an economic force in the South African and local economy. In the 2005/6 financial year, the airport handled 9.0 million domestic passengers, and 7.04 million international passengers (Airports Company South Africa 2006). With this volume of traffic, the airport, similar to airport developments globally, acts like a magnet to a range of industrial and commercial activities and related service industries which serve the airport and its workers (Nagle 2000).

ORTIA's development as South Africa's most important airport is related to a number of factors. Johannesburg has important financial and trading links with much of the world. For example, at the time of writing, there were 38 flights a week to London and 19 flights a week to the United States. Although Johannesburg is not a national capital (it is the provincial capital of Gauteng province), most international flights and therefore people travelling on holiday, business or on diplomatic service fly internationally via ORTIA. As a hub airport, Johannesburg has an advantageous geographic location, a multi-million catchment population and a large number of air carriers and destinations.

These positive benefits of the airport are important – however, there are a number of disadvantages to airport development – chief amongst these being air pollution, road traffic congestion and aircraft noise. Airports and their use can have a major environmental impact on surrounding areas. Aircraft noise is probably the worst environmental impact caused by airports and emerged as a problem as far back as 1952 in the United States when the Doolittle Commission prepared a report for President Truman identifying conflict between airport noise and community land-use as a future national problem (Bragdon, 1973). Horonjoff & McKelvey (1983) consider aircraft noise to be the most severe environmental problem in the development of airports, and Ashford, Stanton & Moore (1984) state that aircraft noise is a worldwide problem which can constrain the operation of existing airports.

Bryant (in De Roo & Bartelds 2000) states that the resolution of land-use compatibility conflicts between noise sensitive land-uses and the acoustically intrusive activities associated with the operation of an urban airport, requires a three-pronged approach. Firstly, noise abatement programmes relate directly to noise reduction at the source such as aircraft and engine types, flight procedures and flight tracks. Secondly, noise mitigation programmes reduce the effects of noise on the community through building insulation and property acquisition. The third prong is compatible land-use planning and involves cooperation with those who control land-use. Noise contours based on aircraft operations are produced for airports. These contours are linked to social surveys which give average levels of irritation expected from the community as aircraft noise levels increase. For example, in the United States, 65DNL is regarded as the limit above which certain land-use types, particularly residential, should not be permitted in the vicinity of airports. Typically, the noise contours are then used to guide the land-use planning process so as to keep noise sensitive land-uses away from the aircraft noise.

In South Africa, Standards South Africa prescribe the standards whereby aircraft noise should be calculated for land-use planning purposes. These standards were updated in 2004 after extensive consultation. This author was a member of the working group tasked by the then SABS to revise these standards. The relevant old standards were referred to as SABS 0113 and SABS 0117, and the new standards as

SANS 10113 and SANS 10117. These new standards link to World Health Organisation (WHO) documents as their starting point.

It has become evident, however that more and more complaints about aircraft noise originate from areas outside of the published noise contours (Commonwealth Department of Transport and Regional Services 2000) and that complaints depend in part not only on the noise level but also the time of day that the noise occurred, and the number of noise events heard (Hume, Gregg, Thomas & Terranova 2003). Wijnen & Visser (2003) and Quehl & Basner (2006) found that noise levels which are tolerated during the day may be found to be unacceptable at night with great efforts being put into reducing the problem. Ohrstrom, Hadzibajramovic, Holmes & Svensson (2006) reported that placing a transparent plastic pane over a window reduced noise level by 11dBA.

Further compounding the problem of understanding aircraft noise are differences in individual responses to noise. Job (1993) cited evidence that a large proportion of the variation in reaction to environmental noise is accounted for by psychosocial factors. Hume et al. (2003) report that a complex relationship exists between annoyance and stress, in noise affected residents living near airports. An individual who is already stressed may find aircraft noise more annoying. The causality can be reversed as stress can lead to annoyance reactions (Kryter 1985).

Whilst SANS 10113 and 10117 follow international best practice in calculating cumulative noise exposure, and in recommending suitable land-use planning, it will be shown that these standards may not always suffice as evidenced by people who are still disturbed by aircraft noise even though they reside outside noise contours.

2.7 HOW AIRPORTS DEAL WITH NOISE PROBLEMS

Many large, busy airports around the world have noise and track monitoring systems, and information about aircraft flight tracks and noise is made available to the public. Sometimes this information is published by airports in a regularly produced report, whilst other airports have linked their noise data to a website where flight track and noise information is available, usually with a short delay due to security concerns.

These airports usually have a community relations department which deals with complaints by surface mail, e-mail, dedicated phone line during office hours and an answer phone at other times (Hume et al. 2003). The information is used to refine or restrict operations in order to minimize disturbance.

This advanced type of noise and track monitoring technology is not used in South Africa, although most of the major airports have, to some extent, formulated a mechanism to log and respond to complaints about aircraft noise. A further use for aircraft noise and track monitoring systems is to provide information which may be used to guide land-use planning in the vicinity of airports where residents are likely to be exposed to disturbing noise from aircraft.

2.8 DEALING WITH AIRCRAFT NOISE: SOUTH AFRICAN FRAMEWORKS

There are many national bodies and organisations which have some responsibility for addressing quality of life in urban environments. Since noise, particularly aircraft noise, may be regarded as a quality of life issue it is useful to explore the responsibility and accountability of dealing with aircraft noise.

In 1976, the United Nations held its first conference on human settlements, also known as Habitat 1. In 1992 the United Nations Conference on Human Development was held in Rio de Janeiro out of which the well-known Agenda 21 arose – a document detailing how countries may work towards global sustainable development. In 1996, Habitat II was held in Turkey, and in 2002 the UN Habitat agency’s mandate was strengthened and its status elevated to that of a fully fledged programme of the UN system (United Nations 2003). In the discourse of urban sustainability, these organisations make recommendations, designed to improve living conditions within urban areas but don’t really have the teeth to enforce these.

2.8.1 The South African Constitution

The constitution of a country contains the most important rules of law concerning the political system of a country (Rautenbach & Malherbe 2004). Government in South

Africa consists of the national, provincial and local levels, which are distinctive, but also interdependent and interrelated. Government may intervene at any of the three levels to protect its citizens from negative environmental impacts. The South African Bill of Rights in Chapter 2 of the Constitution includes not only an environmental clause but a number of other clauses which have made, or have the potential to make significant contributions to environmental justice in the country (Glazewski 2002). In particular, subsections 24(a) of the environmental clause of the bill of Rights in Chapter 2 of the Constitution provides that "Everyone has the right … to an environment that is not harmful to their health or well-being" (South Africa 1996: 8) and 24(b) "Everyone has the right … to have the environment protected … through reasonable legislative and other measures that … prevent pollution and ecological degradation" (South Africa 1996: 8). The constitution may thus be interpreted to offer some protection for those who are disturbed by aircraft noise if it is accepted that noise is harmful to their health or well-being.

If the Constitution is interpreted to offer some protection, then the question may be asked: Under which jurisdiction does aircraft noise pollution lie? Is it national, provincial or local government? And which departments' skills and expertise are required to deal with it? Is it a matter for environmental affairs, town and regional planning, transport, health? The following have some bearing on answering this:

- Section 125(2)(b) of the Constitution states that provinces are responsible for "… implementing all national legislation within the functional areas listed in Schedule 4 or 5 except where the Constitution or an Act of Parliament provides otherwise" (South Africa 1996, 53).

- Section 155(6)(a and b) of the Constitution states that provincial governments must establish municipalities. Section 156(1)(a) explains that municipalities have the executive authority to administer the local government matters listed in Part B of Schedule 4 and Part B of Schedule 5 (South Africa 1996).

- Schedule 4 of the Constitution stipulates that a provincial executive is responsible for implementing all national legislation in the schedule. Of possible relevance to dealing with the issue of airport noise in the schedule in Part A are:

- Airports other than international and international airports
- Environment
- Pollution control
- Regional planning and development
- Urban and rural development

and

Part B refers to:

- Municipal airports
- Municipal planning
- Municipal health services (South Africa 1996).

It is evident that whilst the constitution provides some guidance, one must look elsewhere for more detailed direction. This is provided in the National Environmental Management Act and the Environment Conservation Act.

2.8.2 The National Environmental Management Act and the Environment Conservation Act

The National Environmental Management Act 107 of 1998 sets out environmental management principles that provide the basis for environmental management (South Africa 1998). Noise is a form of pollution as defined by the act but other than this brief definition, the act is silent on noise. This is in contrast to international examples where the basis of the regulatory approach is some form of licensing, planning, zoning or monitoring, aimed at creating a socially optimal level of environmental quality. (De Roo & Bartelds 1996; Eckdish Knack & Schwab 1986; Goodall 2000; Pacione 2001; Thomas 1996). Regulatory instruments therefore should have a direct influence on noise pollution since compliance is mandatory. However, the approach is often designed to be flexible and the rules are tailored to individual circumstances which means they may not be as effective. Goodall (2000) adds to the regulatory framework economic instruments and voluntary instruments to bring about compliance.

The Environment Conservation Act 73 of 1989 has a broad definition of 'environment' which means that noise pollution is included in its purview (Glazewski 2000). Section 25 of the Act states that the minister may make regulations with regard to the control of noise, vibration and shock (South Africa 1989). Acting in accordance with this empowering provision, the environmental ministers of two provinces – the Western Cape and Gauteng - have made noise control regulations which these provinces have adopted (Province of the Western Cape 1998; Province of Gauteng 1999). They are detailed in the next section.

2.8.3 Provincial noise regulations

Gauteng's regulations are pertinent to this research as the study area is in this province. The regulations adopt a number of technical terms and standards. Section 1(b) of the Gauteng Noise Control Regulations includes reference to the South African Bureau of Standards' publications *SABS 0103-1997 The measurement and rating of environmental noise with respect to annoyance and speech communication* and *SABS 0117-1974 Code of practice for the determination and limitation of disturbance around an aerodrome due to the noise from aeroplane*, both as amended from time to time, or their corresponding replacements. Both standards were amended in 2003.

Section 11(1)(a) of Gauteng's GN5479 gives local authorities the authority to designate a controlled area in its area of jurisdiction. A controlled area in the case of an airfield is taken to mean a piece of land where the calculated noisiness index, projected for a period of 15 years following the date on which the local authority made such designation, exceeds 65dBA. Section 11(2)(a) states that no educational, residential, flat, hospital, church or office buildings may be erected within a controlled area for which a zone sound level has been designated. Section 11(2)(b) states that no educational, residential, hospital or church erven may be situated within a controlled area for which a zone sound level has been designated (Province of Gauteng 1999).

In the Western Cape (Section 2(c)) (Province of the Western Cape 1998) and in Gauteng (Section 14(b)) (Province of Gauteng 1999) if, in the opinion of the local authority, a noise is a disturbing noise, or noise nuisance, the local authority may instruct the person responsible for causing the noise to either discontinue the noise or lower the level to conform with requirements of regulations. It is important to note that in respect of noise caused by air traffic, the provision shall not apply. This is a critical observation since in the law it is evidently difficult for the provincial authorities to take action. Whilst land-use planning can have a role to play in dealing with aircraft noise, local authorities have no jurisdiction over noise from air traffic.

The statutes mentioned above all involve or imply that land owners have limitations placed upon their rights. These limitations or controls imply a restriction upon the freedom of owners to use and exploit their property according to their discretion. The question that must be asked is whether land owners in the vicinity of airports are able to use their land at their discretion if noise from aircraft interferes with their activities. Municipalities impose restrictions on the use of land, but other restrictions like noise may come into play. The next question which arises is whether land owners are entitled to some sort of redress for the effect of noise upon their rights to use of their land. Let us assume that aircraft have to use land to make noise. If the land is not available to them for this purpose, then they cannot fly. What compensation measures are available to land owners if the extent of the use of their land is inhibited by aircraft making noise? Claassen & Milton (1992) mention that expropriation, injurious affectation and tax relief are provided for in the ordinances. However, many prevalent forms of disturbance are excluded, rendering compensation largely ineffective. Clearly, the law in South Africa presently does not provide for any compensation due to noise.

2.8.4 The national government's position on aircraft noise

In 1999, the then Minister of Transport announced that the Department of Transport had developed a draft policy document on aircraft noise and engine emissions following the International Civil Aviation Organisation's (ICAO) resolutions to have a policy framework in place regarding environmental issues, and the worldwide trend relating to minimising the impact of aircraft noise and engine emissions on the environment (Omar 1999). It was also conveyed in the announcement that the draft policy had the broad support of stakeholders and would be finalised shortly. Since then though, there appears to be a reversal, or at least a reconsideration, of this stated position.

Three quotes are relevant.
Firstly, at the Ninth Aviation and Allied Business Leadership Conference, the then Minister Dullah Omar stated that:

> "The area of aircraft noise and engine emissions requires a balance to be established between the interests of airport operators and the public affected by aircraft noise and engine emissions. We need to find mechanisms to ensure that noise abatement procedures are developed and adhered to. One difficult area is the phasing out of chapter 2 aircraft and the non-addition of these aircraft on to fleets of both domestic and international operators. This is largely a safety issue as most of these aircraft will be around 30 years old by the end of the 7-year period" (Omar 2003).

Secondly, at the 17th Plenary Session of African Civil Aviation Commission, Mr Omar's successor, Mr J Radebe, addressed the issue of aircraft noise. He spoke about the

> "… need to come up with appropriate yet realistic timeframes for the implementation of suitable regulations governing aviation environmental protection. The most obvious one in this regard is noise. The extent to which developed world concepts such as acceptable level of noise pollution in an urban setting can be carried into other parts of the world is a debate I do not want to entertain here, but the fact remains that we should examine whether the 'one size fits all' approach will address the issue adequately" (Radebe 2004a, no page number).

At the Airlines Association of Southern Africa Annual General Meeting and Conference he stated that

> "I would understand that all our airlines at one point or another have faced significant fines at European and North American airports, so there is another commercial angle to the issue as well. Nevertheless, ICAO has moved forward

> with an accommodation of some of Africa's concerns on this score and we need to develop an approach to see implementation in as practical a manner as possible. Naturally, sooner or later the question of reducing and controlling engine emissions and other aviation pollutants must also be dealt with. But once again, these are issues that are related in part to the question of aging air-fleets, and the application of often-costly new technologies, and of adequate maintenance facilities" (Radebe 2004a).

Thirdly, at the Airlines Association of Southern Africa Annual General Meeting & Conference held on 15 October 2004, Minister Radebe spoke as follows:

> "…ICAO made some progress concerning the thorny issue of the environment, particularly emissions and noise pollution. Whilst everyone is concerned about emissions and noise, it is quite clear that for many states, particularly those in the developing world, these issues do not rank in the immediate priority list of social needs. ICAO has committed itself to getting some resolution on the matter by 2007, and in the meantime has indicated that no unilateral penalty system can be imposed on states until that time" (Radebe 2004b).

While recognising that the issue of noise remains a problem, the position taken is one of questioning the current approach taken by the international community in the light of penalising the aviation industry in developing countries for infringing noise limits. The consequences of delaying a decision on an aviation environmental policy could however be severe. The Organisation for Economic Co-operation and Development (1986) recognised that problems can result from 'no-change' policies. In their report on the state of the noise environment, they highlight the problem of 'grey areas' where the "… number of people who, while not in a wholly unacceptable situation, cannot be said to enjoy 'acoustic comfort', will increase substantially." (Organisation for Economic Co-operation and Development 1986: 25). As more residential development takes place close to airports, residents are exposed to more noise, firstly because they are closer, and secondly as more flights take to the skies. Eventually, as has been the case in other parts of the world, authorities have been forced to take action which often has expensive or inconvenient consequences. Noise insulation of houses, and financial compensation are expensive options – inconvenience may for example take place when airports operating hours are restricted to those times when noise is judged to be most disruptive.

2.9 DEALING WITH AIRCRAFT NOISE: INTERNATIONAL FRAMEWORKS

There are a wide range of international organisations who provide guidance on urban environmental sustainability and dealing with noise in general, and aircraft noise in particular. In this section they are discussed.

2.9.1 Agenda 21

Agenda 21 – essentially an agency for the environment for the 21st century – was conceived at the Rio conference in 1992. The United Nations' Agenda 21 supports a number of environmental management principles on which government policies, including noise management policies, can be based.

These include:

The precautionary principle. In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health without awaiting full scientific proof.

The polluter pays principle. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision) should be met by those responsible for the source of noise.

The prevention principle. Action should be taken where possible to reduce noise at the source. Land-use planning should be guided by an environmental health impact assessment that considers noise as well as other pollutants.

Local authorities worldwide have devised their own locally negotiated proposals for an environmentally sustainable environment. Known as LA21s, one of the key aims is to encourage participation and involvement of all members of society in a process through which they can identify their needs and bring these needs into decision-making arenas (Evans & Percy 1999).

The recommendation that land-use planning be guided by an environmental health impact assessment that considers noise as well as other pollutants is an important one which will be revisited in Chapter 6.

2.9.2 World Health Organisation

The World Health Organisation has published guidelines to be considered when dealing with noise (World Health Organization Regional Office for Europe 2001). Environmental noise, specifically noise from aircraft is acknowledged as a problem to be dealt with. The stated goal of noise management is to maintain low noise exposures, such that human health and well-being are protected. The specific objectives of noise management are to develop criteria for the maximum safe noise exposure levels, and to promote noise assessment and control as part of environmental health programmes. A sufficient distance between the airport and residential areas will make noise minimal, although this is not always achievable (World Health Organization Regional Office for Europe 2001).

The WHO also expects substantial growth in air transport in the future. Large international airports may have to accommodate an increase in passenger movement numbers and general aviation noise at regional airports is also expected to increase. Although jet aircraft have become less noisy due to regulation of noise emissions, the number of passengers and therefore flights is expected to increase. In Germany, increased air traffic movement between 1980 and 1990 is considered to be the main reason for the average 22% increase in the number of people exposed to noise above 67 dB L_{Aeq} at German airports (Berglund, Lindvall & Schwela 1999).

2.9.3 International Civil Aviation Organisation Annex 16, and Balanced approach

The International Civil Aviation Organisation has published standards for noise certification which aircraft manufacturers must comply with. These standards have had a significant effect on reducing noise emissions from aircraft. Aircraft certified according to Annex 16, Chapter 4 (which was implemented in 2006) comply with the most stringent requirements (Bottcher 2004). However, the way the aircraft are operated and maintained by operators will have a bearing on attainment of ICAO standards. The ‘Balanced Approach to aircraft noise management’ was endorsed by ICAO in 2001 (International Civil Aviation Organisation 2004). Part of this approach is the need to implement suitable land-use planning and management.

2.9.4 Airports Council International (ACI).

Whilst supporting the balanced approach favoured by ICAO, the ACI has devised its own aircraft noise rating index. The index provides airports with a common tool to rate all aircraft which operate into the airport on the basis of the certificated noise levels relative to ICAO Chapter 3. Although not a computerized model, it can nevertheless be regarded as an aircraft noise prediction model which is used to provide aircraft noise information. The index was selected because it gives information about the status of an aircraft relative to the state of the art in aircraft noise reduction technology. The index can be used to encourage airlines to use quieter aircraft and, as an incentive to manufacturers, to develop and market the quietest aircraft possible. It can also be used to communicate with neighbouring communities, local authorities, and regulators.

2.9.5 Examples of National Standards in the United Kingdom and USA

Economic instruments imply the polluter pays principle. The cost incurred by the polluter ensures that the polluter attempts to change its behaviour to reduce this cost, and which eventually reduces the pollution to an acceptable level. In the United Kingdom at Heathrow, Gatwick and Stansted airports, fines are levied on airlines which do not comply with noise limits (Department for Transport 2005). Economic instruments, although provided for in the South African White Paper on Aircraft Noise and Engine Emissions have not yet been implemented in South Africa.

Voluntary instruments imply an integration of environmental quality into the total quality management of a company. Companies, instead of being reactive, switch to anticipatory modes of behaviour without waiting for government action. This has happened in the aviation industry to some extent, where airlines are operating quieter aircraft now than a decade ago. The primary reason is that newer aircraft are far more fuel efficient than older types. The added benefit is that these aircraft are also quieter.

In the United Kingdom, when assessing residential developments near a source of noise, including airports, local planning authorities are required to heed the advice of four Noise Exposure Categories (Department for Communities and Local Government 2006). However, the wording is couched in words such as 'advice', 'recommendations' and 'guidelines' creating plenty of flexibility for local planning authorities to interpret things as they please. British Airways recognises the importance of planning but criticises the statement in the document that there is a "… balance to be made between noise and the pressure for housing development, which severely compromises the effectiveness of this document" (British Airways 2006). The airline is concerned that if planning for housing does not keep residences away from an airport, in time the airport's activities will be curtailed by complaints, which in turn will affect the airlines.

Planning is limited in its ability to bring about improvements in the noise around airports for existing land-use activities. Any conditions or standards which are imposed at the time planning permission is granted become outdated as aircraft types change, movements increase, and society's environmental aspirations increase (Goodall 2000).

The Federal Aviation Administration in the United States has developed an extensive noise modelling and land use planning tool. Colloquially known as Federal Aviation Regulations (FAR) Part 150, this statutory requirement is prescribed for airport noise compatibility planning (Federal Aviation Administration 2003).

2.10 URBAN SPATIAL AND LAND-USE PLANNING IN THE VICINITY OF AIRPORTS

The term planning is derived from the noun plan, which can be defined as 'a method of doing something that is worked out in some detail before it is begun; a drawing or diagram showing the layout, arrangement or structure of something' (Rooney et al. 1999). In the case of town and regional planning, the goal to be achieved by planning is to improve the quality of life and wellbeing of the community concerned (Claassen & Milton 1992; Singh 2000; Wagner 2000). One of the means to achieving this goal is land-use planning. Claassen & Milton (1992) divide town and regional planning into two interdependent functions. One deals with the ideal arrangement of land-uses based on theories. However, because of the subjective nature of what people believe to be ideal, and resultant conflicting expectations, an ideal is unachievable. The second function which Claassen & Milton (1992) discuss is that town and regional planning should provide a fair, just and efficient process for deciding on land-uses. One important function of town and regional planning is to prevent unhealthy living conditions in cities, one such condition being airport noise. Other functions are to limit diminution in residential property market values experienced internationally around airports as a result of airport noise (Bell 2001) and to limit conflict between land developers and airport management (May & Hill 2006).

How effective is planning in this role? Todes (2006) holds the view that in the early post-apartheid period, there were severe constraints on planning policy with a weak and fragmented local government system, the emphasis being on making cities safe for capital. This led to an expansion in development in urban areas with little or no thought for future consequences.

Zoning land for a particular use does not initiate development. Other factors such as the intentions of the land owner and market forces carry more weight. This is a weakness of town planning. With large numbers of people migrating from rural hinterlands to urban areas, land-use planning has been reactive and not pro-active. Reactive planning reacts to problems that occur whilst pro-active planning anticipates and prevents problems. Claassen & Milton (1992) state that planning is often seen as a Western concept which can be an obstruction to development. This would indicate that reactive planning is used to deal with problems so that pro-active planning does not get in the way of socio-economic development.

The concept of sustainable development i.e. development that "… meets the needs of the present without compromising the ability of future generations to meet their own needs …" (Mayhew 2004: 480) has also been taken into town and regional planning, so indicating that both development and conservation are imperative to the process.

Gilbert, Stevenson, Girardet & Stren (1996) maintain that the role of local governments in ensuring well-functioning cities is important in making progress towards sustainable development goals and programmes. Issues related to cities are addressed throughout Agenda 21; for example Chapter 7 deals with protecting and promoting human health, where noise is recognised as having a severe impact on the urban environment (United Nations 2005). Claassen & Milton (1992) contend that town planning is becoming more process orientated than blueprint orientated. This means that it is striving to become a people orientated system, to be used by the whole community and to which a wide range of professions contributes. It is essential that the system by which decisions are taken is fair and democratic so that the will of the majority prevails. Claassen & Milton (1992) show that the local level of town planning goes a long way to provide such a system. Claassen & Milton (1992) state that town and regional planning operates at three levels: local, regional and national. Local planning is well developed, the emphasis being on physical planning and control, and various town-planning ordinances are in place at a local level too. Environmental problems cover a wide range of topics and are to be found at various scales (Claassen & Milton 1992). Many of these problems fall outside of the town and regional planning organisational framework. Certain environmental aspects can be addressed through town planning, and one of these is noise.

Claassen & Milton (1992) are critical of town planning schemes, stating that instead of these being policy documents for future development, they were development control mechanisms. The Ekurhuleni Integrated Development Plan published in 2003 (as required in Section 25(1) of the Municipal Systems Act) seems to recognise previous shortcomings and addresses them in a strategic planning instrument (Ekurhuleni Metropolitan Municipality 2003b), something envisaged earlier by Claassen & Milton (1992).

2.11 URBAN PLANNING UNDER APARTHEID

No writing on urban planning in South Africa can be complete without reference to urban planning under apartheid. Apartheid-style urban divides are not unique to South Africa, but in many cases communities were relocated under Group Areas removals to places with poor access to urban services and facilities (Todes 2006) and areas which had other unpleasant characteristics – for example near Cape Town and East London airports where noise was set to become a problem. In South Africa today, particularly around Cape Town International airport, residents are vulnerable to aircraft noise as the airport's traffic is predicted to grow (Van der Merwe & Von Holdt 2005).

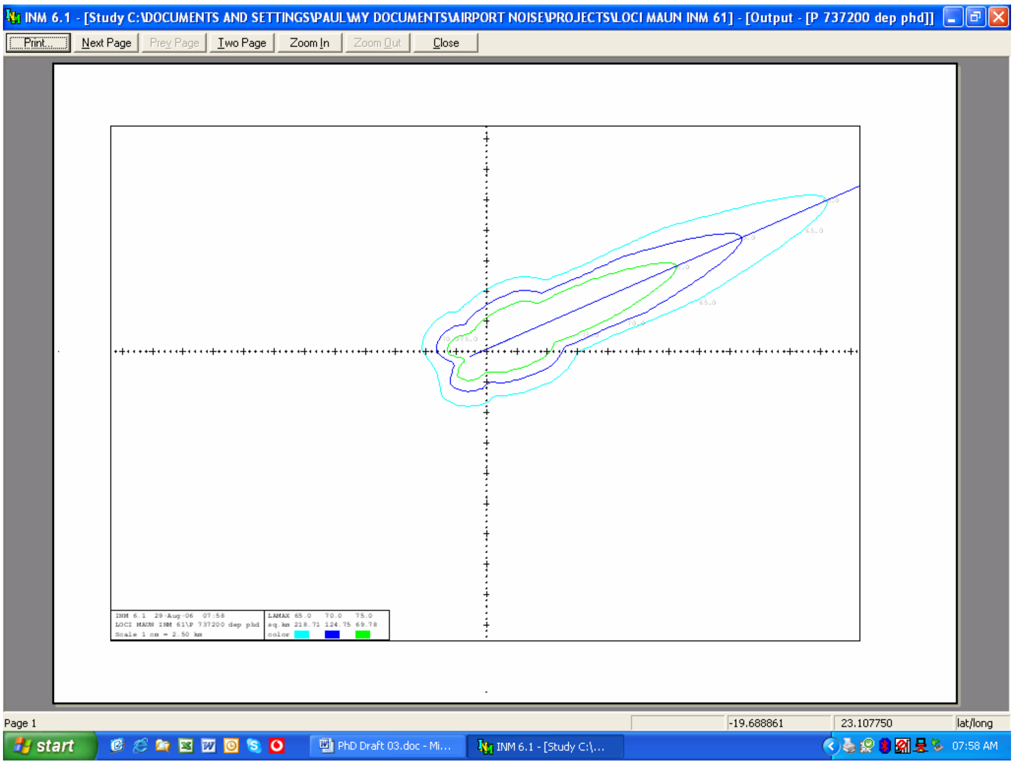
Up until this point in this study, discussion has centred around land-use planning based on average energy aircraft noise contours. In the following section, supplemental aircraft noise information will be discussed.

2.12 SUPPLEMENTAL AIRCRAFT NOISE INFORMATION

It is an important argument in this dissertation that average energy aircraft noise contours do not provide enough information to lay-persons about the noise they are likely to be exposed to around airports. Average energy contours do not show the user how many flights the contours represent, or what the noise levels of these flights are. The terms supplemental noise information and transparent noise information have been employed to describe the efforts made to expand on the average energy information. Members of the public are interested in being provided with aircraft noise information in a form to which they can readily relate.

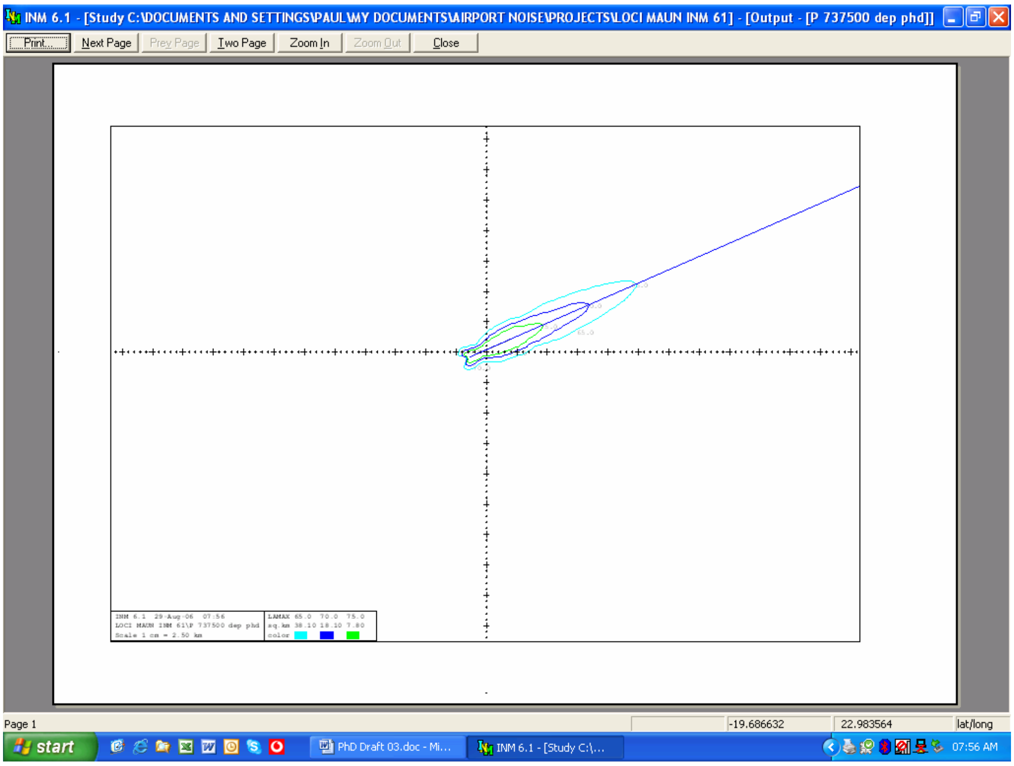
2.12.1 Single events contours

When supplemental aircraft noise information is made available, interest initially focuses on providing information on the maximum dBA level of single aircraft movements as this is the most basic, and easily understood way to report noise (Commonwealth Department of Transport and Regional Services 2000). An interested person would typically be shown single event maximum noise contours of aircraft which operate from the airport in question. Figures 2.4 and 2.5 illustrate examples of two single event departures. Figure 2.4 represents an older generation Boeing 737-200 with a takeoff weight of 56 246kg and static engine thrust of 7 257kg. Figure 2.5 is for a newer generation 737-500 with a takeoff weight of 62 823kg and a static thrust of 9 072kg. Both are produced from data in the Integrated Noise Model. (Although the Integrated Noise Model does not provide a scale representation in these figures, the same scale setup was used as evidenced by the tick marks.)



Source: Federal Aviation Administration (2003).

Figure 2.4: Single event noise contour – departure of a Chapter 2 Boeing 737-200.



Source: Federal Aviation Administration (2003).

Figure 2.5: Single event noise contour – departure of a Chapter 2 Boeing 737-500.

Visual comparison of the contours clearly shows that the noise contour from the newer Boeing 737-500 is discernibly smaller than the noise contour of an older Boeing 737-200 taking off. Even though the new aircraft is heavier than the older one, and has a higher static thrust, the 65dBA maximum noise contour of the new aircraft with its quiet engines is 17% of the size of the older plane's (Table 2.1).

Table 2.1: Spatial extent of single event noise contours of old and new technology aircraft

Aircraft	Static thrust (kilograms)	Weight (kilograms)	Spatial extent of the 65dBA maximum contour (sq km)
Boeing 737-200	7257	56246	218.7
Boeing 737-500	9072	62823	38.1

Source: Federal Aviation Administration (2003).

Having convinced the layperson that newer aircraft make considerably less noise than older aircraft, it is possible that single event contours may be superimposed on land-use maps to enable people to see the predicted noise levels in the vicinity of their homes for a single event movement of the selected type of aircraft. The single event contours help someone to compare the noise levels generated by different aircraft types, landing or take-off phases of flights, and different flight paths. The criticism levelled at single event information is that it can be misleading because it does not give any information about the number of times the noise events will take place (Commonwealth Department of Transport and Regional Services 2000). Number of events contours fulfil this purpose.

2.12.2 Number of events contours

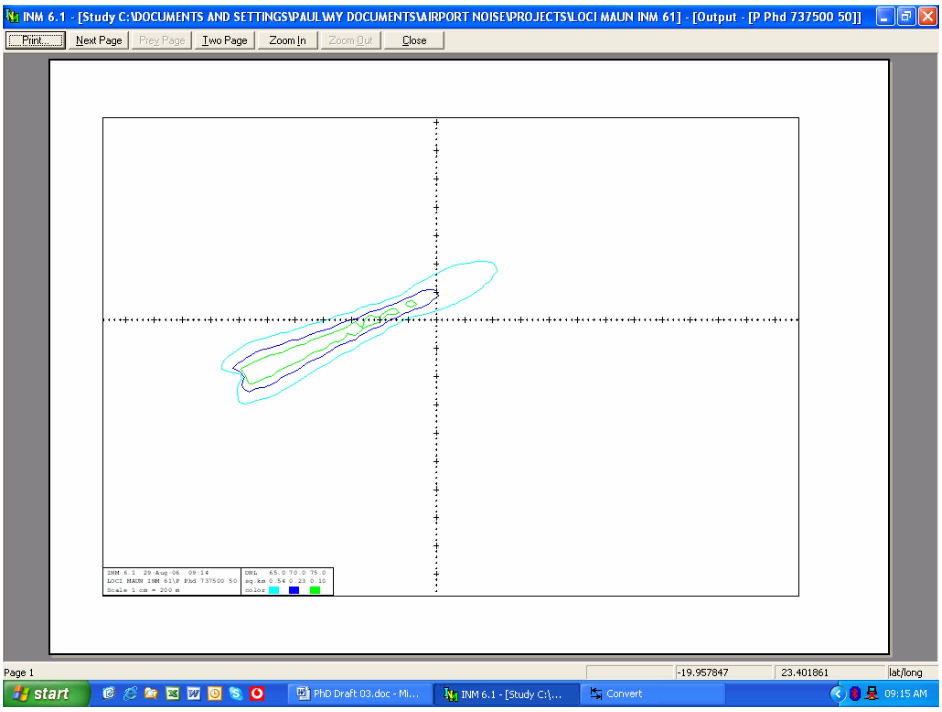
Due to the multiplicity of flight tracks and aircraft types, providing single event aircraft noise information to airport neighbours can become unwieldy due to the myriad combination of aircraft types and possible flight tracks flown. To overcome these problems, contours which communicate the number of events above a specified noise level have been produced for some airports. These contours combine information on aircraft movement numbers with their single event noise levels. Important here is the selection of the noise level to represent, and the numbers of events to show on the contours. Contours showing the number of events louder than 70dBA have been adopted because this is regarded as being equivalent to a level of 60dBA inside a normal house with open windows (Commonwealth Department of Transport and Regional Services 2000). A normal house is regarded to be constructed from brick and mortar, with conventional roofing materials – tiles or corrugated iron.

In South Africa many residential dwellings are not constructed from these materials, so do not provide much protection against noise. Consequently, in this study, it is necessary to set a noise level of 60dBA to account for dwellings which acoustically do not provide much protection. A level of 60dBA is also convenient to represent night-time exposure patterns because an external single event noise level equates to the sleep disturbance level of 50dBA (Commonwealth Department of Transport and Regional Services 2000). Extending noise contours to lower levels raises questions about the accuracy of aircraft noise information, particularly because of interfering noises from other sources, for example road traffic. Number of events contours have advantages and disadvantages and these will be set out in the following section.

2.12.2.1 Advantages of number of events contours

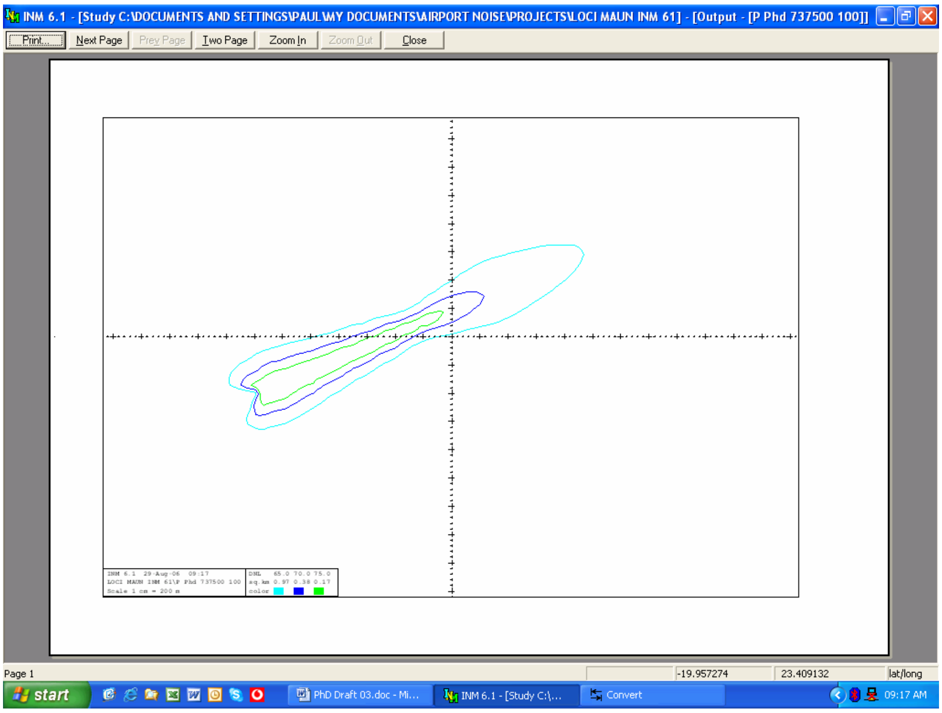
The Integrated Noise Model (INM) is prescribed by SANS 10117 to be used to calculate average energy noise contours. The INM can also be used to compute a grid file which is used as an input into noise modelling software which calculates number of events. This means that the same data used to produce average energy noise contours is used to produce the number of events contours. In turn this means that an understanding of average energy contours can be clarified and expanded upon by using number of events.

The number of events contour is attractive to laypersons in that it is an arithmetic indicator. For example, if the number of events at an airport doubles then, all other things being equal, the number of events contour will double. This is a different outcome to the L_{Aeq} noise metric which is logarithmic and relatively insensitive to change. The difference between the two can be shown graphically.



Source: Federal Aviation Administration (2003), compiled by author

Figure 2.6: 65 L_{Aeq} contour for 50 takeoff movements over a 24-hour period



Source: Federal Aviation Administration (2003), compiled by author

Figure 2.7: 65 L_{Aeq} contour for 100 takeoff movements over a 24 hour period.

Using the INM, the average noise impact ($65L_{Aeq}$) over 24 hours of 50 and 100 departures of a Boeing 737-500 are illustrated in Figures 2.6 and 2.7 respectively[3]. Although the 24-hour average noise contour of the 100 movements is larger than that of 50 movements, it is not twice the size. The spatial extent of the two contours differs by a factor of 1.8 (see Table 2.2). The importance of this difference is that residents around this airport are exposed to twice as many aircraft noise events.

Table 2.2: Spatial extent of 24-hour 65 L_{Aeq} contour: 50 versus 100 movements.

Number of movements	Area of 24-hour $65L_{Aeq}$ contour (sq km)
50	0.540
100	0.973

Source: Federal Aviation Administration (2003).

If an airport has a sophisticated noise monitoring system installed, use of the number of events enables summaries to be made for any given period. If there is no noise monitoring system noise information can be produced by computer modelling. By combining the loudness of events with the number of events, a useful addition can be made to the process of making information transparent. But number of events contours also have drawbacks of which one must be aware.

2.12.2.2 Disadvantages of number of events contours

Members of the public living near an airport often want to be given a comparison between an aircraft noise level and the noise made by a common everyday event. This is especially so when a new airport or runway or flight path is being planned. People living in urban areas are generally exposed to a high number of events louder than say 70dBA on a daily basis – cars, domestic appliances, music etc. However, a statement that the sound pressure level of an aircraft will sound like a car passing down the road

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[3] The 65 L_{Aeq} contours shown in Figures 2.6 and 2.7 are the outermost contour lines. The 70 L_{Aeq} and $75L_{Aeq}$ contour are also shown for comparison. These contours are smaller and closer to the airport.

is misleading. The sound pressure levels may indeed be the same, but the perception of the two events is likely to be different. If people show a strong interest in the noise levels, then the best approach is to let them form their own views by directing them to a place near an existing airport with similar aircraft types operating as the proposed development, where they can compare the levels with the readings on a sound-level meter and with other common noise sources such as road traffic.

Another weakness is that once a noise level is selected for portrayal, for example 70dBA, then noise events greater than 70dBA, for example 80dBA are also registered. There are arguments that this is not important since the N70 is based on the concept that once this noise level is reached the annoyance or activity interference is such that the noise event becomes intrusive anyway. The issue can be addressed by producing a series of number of events contours for other noise levels, e.g. N80. The production of a range of these contours works well when a detailed examination of noise exposure and response is being carried out.

One of the strengths of geography is to integrate subject matter from different fields of study. The purpose of this chapter was to describe the links between geography, town planning and the aircraft noise problem and how people understand and interpret the spatial aspects of the aircraft noise dilemma. It has been shown how mapping average energy aircraft noise contours leads to a better understanding of the problem, and the initiation of finding solutions to noise problems. However, average energy aircraft noise contours remain highly idealised representations of the reality of aircraft noise to which people are exposed. The total noise energy from aircraft operations is averaged out over a 24 hour period typically resulting in averages which are up to 30 dB lower then the maximum noise levels which people actually hear. In Chapter 3, the research methodology which was followed to draw attention to the value of supplemental aircraft noise information in the form of maximum noise levels, is explained.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

Scientific research is defined by Smit (1995) as a critical and purposeful action to collect data and new facts, and provide the correct and lasting interpretation of data and facts. The two main components of scientific research are observation and argumentation and this chapter outlines how the observation component of this dissertation was conducted. The purpose of the spatial sampling was to make inferences about a population where each respondent has a geographical reference or geocoding (Haining 2003).

3.1 TYPES OF AVERAGE ENERGY DESCRIPTORS

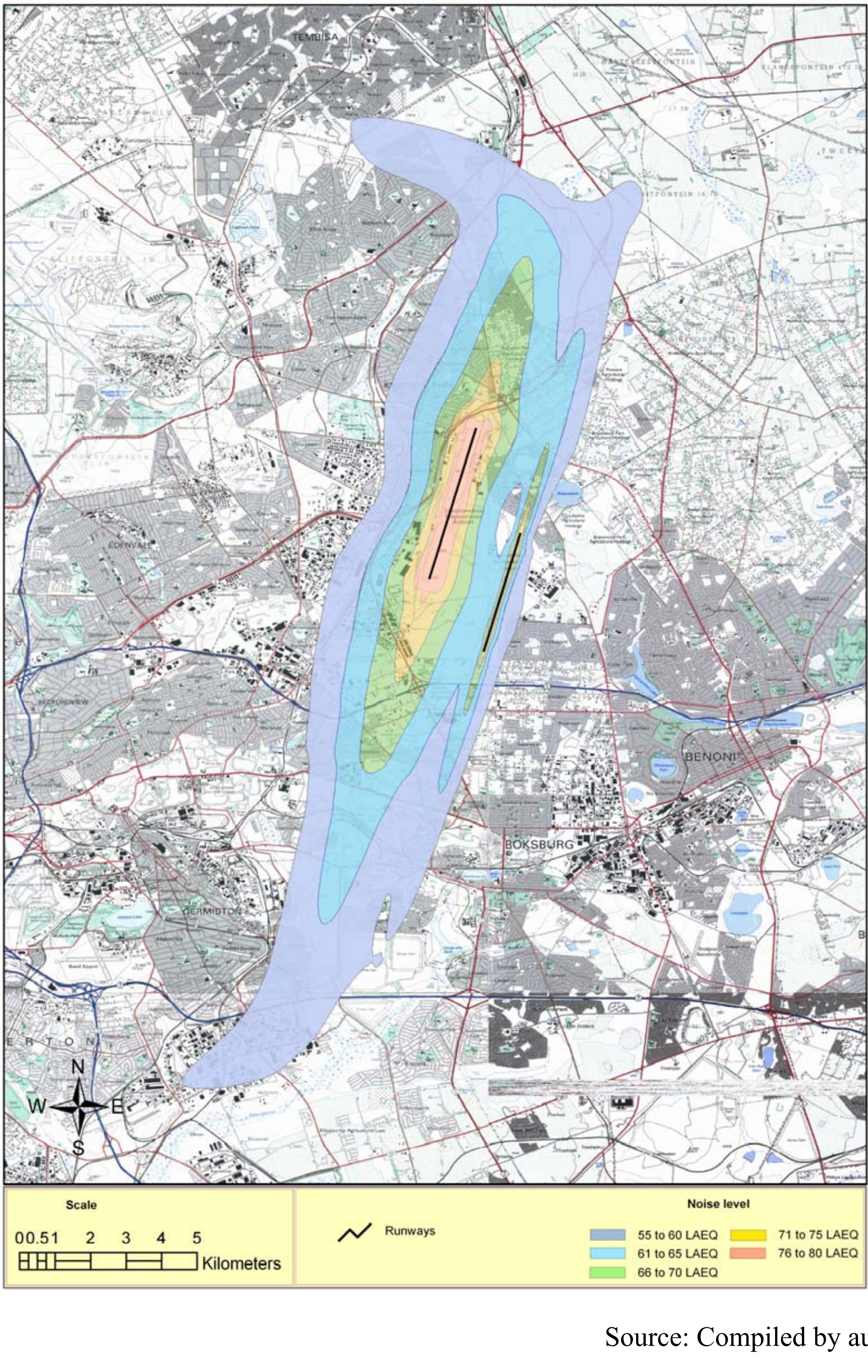
In 2002 ICAO published an updated version of its airport planning manual, in which it surveyed the noise metrics and land-use planning guidelines for 15 of its member states (International Civil Aviation Organisation 2002). A wide variety of noise metrics and land-use planning guidelines were discussed, for example the American DNL, British L_{Aeq}, the French Index Phosphique and German Korsten units. Most average energy noise metrics use some form of weighting to account for the noise created by aircraft at night. Debates still continue as to what time-span the weightings are applied to, and what the value of a weighting should be.

The L_{Aeq} 24 descriptor is the equivalent noise level in dB(A) and is probably the least complicated average energy noise metric to understand, as it averages aircraft noise over a 24-hour period with no weighting and therefore no time period to be weighted. Since weightings, their values, and the period of time applied to them are and will continue to be up for scrutiny, a simple average energy descriptor has received some acceptance.

Some aircraft noise descriptors have weightings applied to the noise from aircraft flights which take place at night-time when communities are regarded to be most susceptible to noise. The DNL as used in the USA, has a 10dBA weighting for flights which take place between 22:00 and 07:00. In South Africa, the NI descriptor (which was in use until 2003) had a weighting of 5dBA applied to flights between 18:00 and midnight, and 10dBA to flights between midnight and 06:00. Flights taking place between midday on Saturday and midnight on Sunday had a weighting of 5dBA applied to them (South African Bureau of Standards 1974). The L_{Rdn} (in use in South Africa since 2003) is conceptually similar to the DNL, adding 10dBA to flights between 22:00 and 06:00 (Standards South Africa 2003).

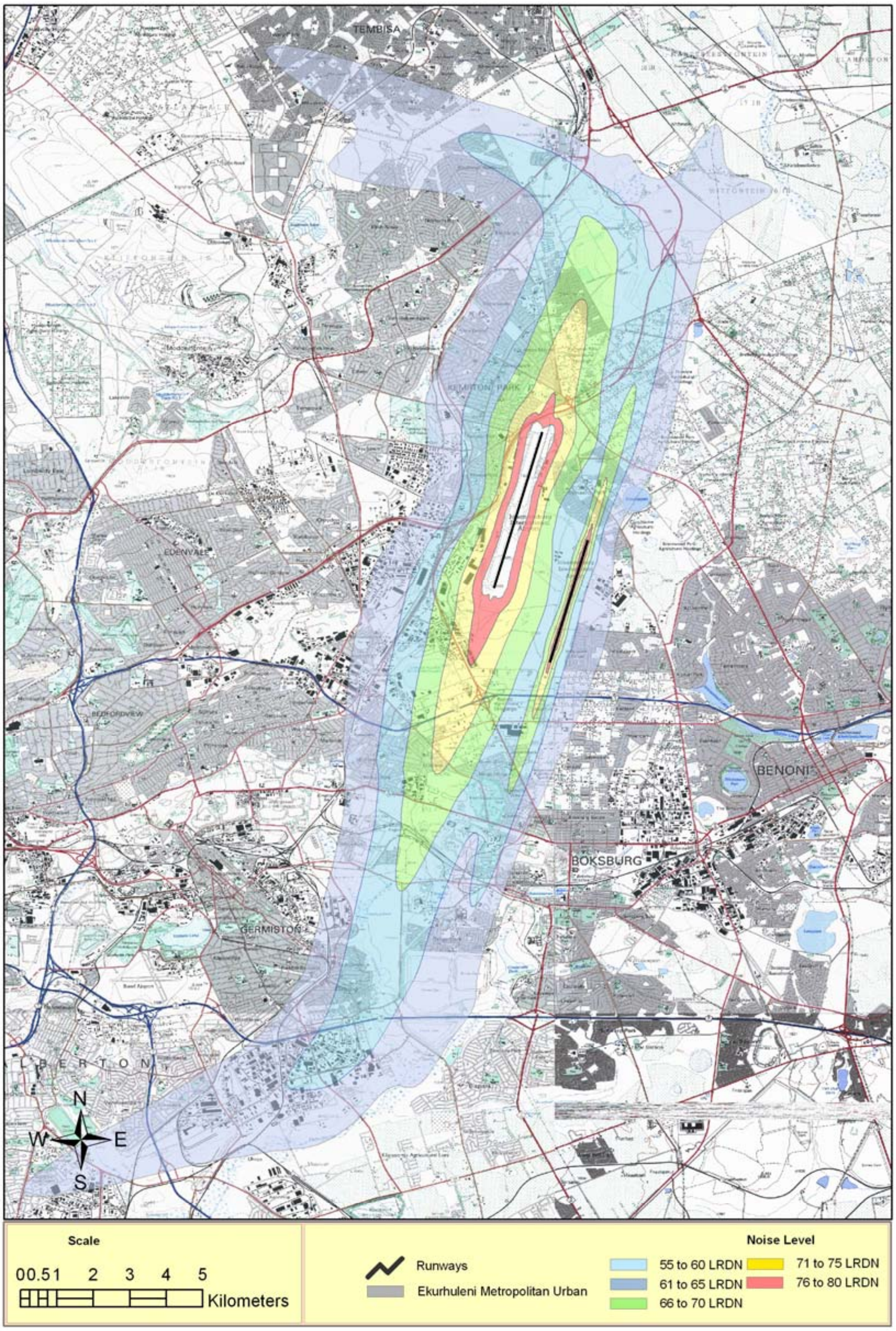
As part of the SABS review of the noise modelling methodology in 2001, the researcher produced noise contours representing four noise metrics (Goldschagg 2001). The same flight operation records were used to calculate the spatial extent of the contours. The only variable that changed was the respective metric's weighting. The flight operations for each metric were grouped according to the time of operation since this affects the weighting which in turn influences the calculated noise level and in turn the spatial extent of the contour.

The differences in spatial extent of noise descriptors is illustrated by the size and shape of contours produced according to these descriptor methodologies in Figures 3.1 to 3.5. For example, consider the 55dB contour (Figures 3.1 to 3.4), the spatial extent of which varies from just over 100 square km for the L_{Aeq} to nearly 200 square km for the NI (Figure 3.5). The area of this contour almost doubles from one calculation method (L_{Aeq}) to another (NI). The variation is due to the weightings used. It is easy to see how the layperson may become confused by the size and shape of the contours if the rather complicated underlying assumptions are not clearly understood, particularly as the same aircraft movement data is used to calculate the four contour sets. It is also clear that from the proximity of houses to the airport, and that no matter which noise metric is used, little attention was given to aircraft noise or that aircraft noise becomes more of a problem because of airport growth. Town planners would need to take care to apply the correct land-use planning guidelines based on the appropriate noise contour. Each of the four contour metrics is described in turn.



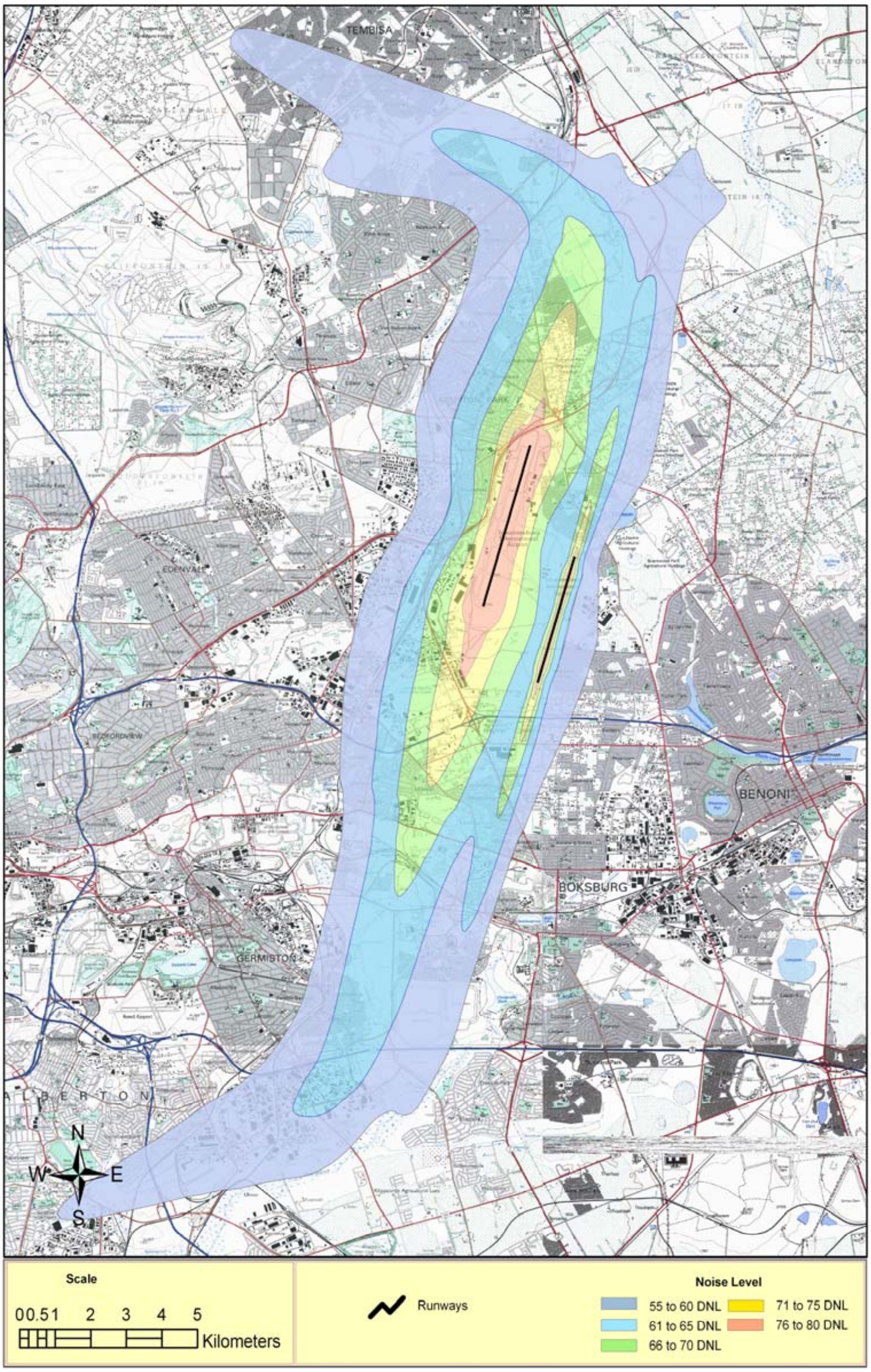
Source: Compiled by author

Figure 3.1: L_{Aeq} noise contour for ORTIA



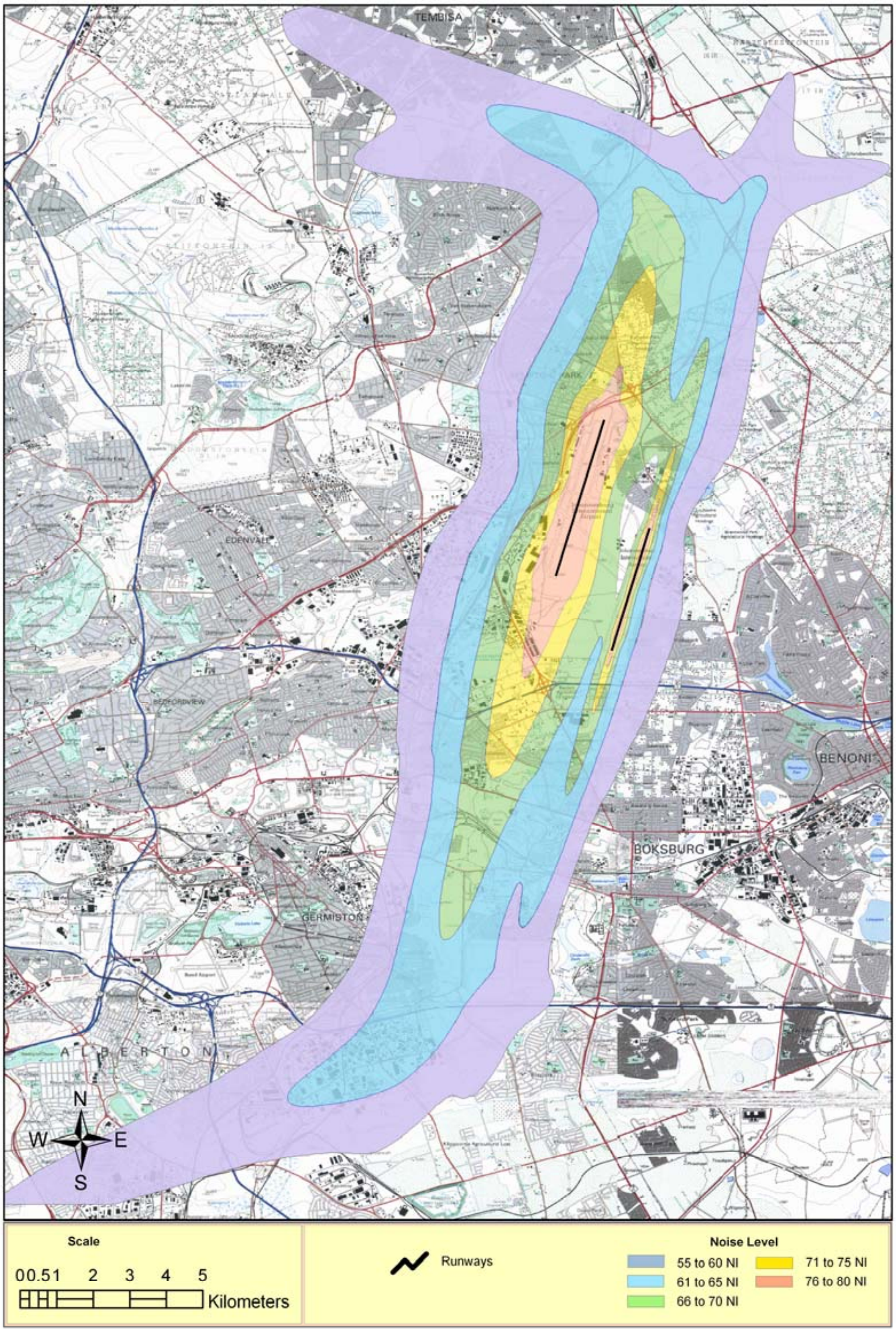
Source: Compiled by author

Figure 3.2: L_{Rdn} noise contour for ORTIA



Source: Compiled by author

Figure 3.3: DNL noise contour for ORTIA



Source: Compiled by author

Figure 3.4: Noisiness Index for ORTIA

3.1.1 L_{Aeq} noise contour

Of the four contours examined here, the L_{Aeq} contour (Figure 3.1) has the smallest spatial extent. There are no weightings or time periods applied to the calculation of this contour. Without weightings to consider, it is the simplest contour to understand of the four discussed here.

3.1.2 L_{Rdn} noise contour

The L_{Rdn} noise contour (Figure 3.2) represents the aircraft noise impact currently prescribed by South African National Standards. A weighting of 10dB is applied to flights occurring between 22:00 and 06:00. This implies that flights between these times must be identified, and classified as such, so that the noise modelling software will perform the calculations based on the appropriate time and weighting. The spatial extent of the L_{Rdn} contour is third largest of those discussed here.

3.1.3 DNL noise contour

The DNL contour (Figure 3.3) represents one of the metrics more frequently used to illustrate noise impact. A weighting of 10dB is applied to aircraft movements taking place between 22:00 and 07:00. The metric is prescribed by the Federal Aviation Administration in the United States and is in common use in that country. The DNL metric is frequently quoted in noise studies, probably for no other reason than airports wish to compare themselves with other airports, and the United States is the most prolific producer of noise contours as it has the greatest number of aircraft movements worldwide. The DNL contour has the second largest spatial extent of those shown here.

3.1.4 Noisiness Index

The Noisiness Index (NI) contour (Figure 3.4) represents the noise from aircraft as calculated according to the prescribed South African standard prior to the introduction of the new standard in 2003. A weighting of 5dB was added to flights operating between 22:00 and 24:00, and 10dB to flights between 24:00 and 06:00. This contour has the largest spatial extent which is attributable to the additional weightings over the weekend time period when compared with the other two weightings which have weightings applied to them.

3.1.5 Comparison of noise metrics' areal extent.

In Figure 3.5, a comparison between the spatial extent of the noise contours is shown according to noise zones. The same aircraft operational data are used for the four noise contour calculations yet the spatial extent differs quite markedly, especially between the areas of the NI contour and the L_{Aeq} contour, viz. the spatial extent of the 60NI contour is almost as large as that of the $55L_{Aeq}$ contour.

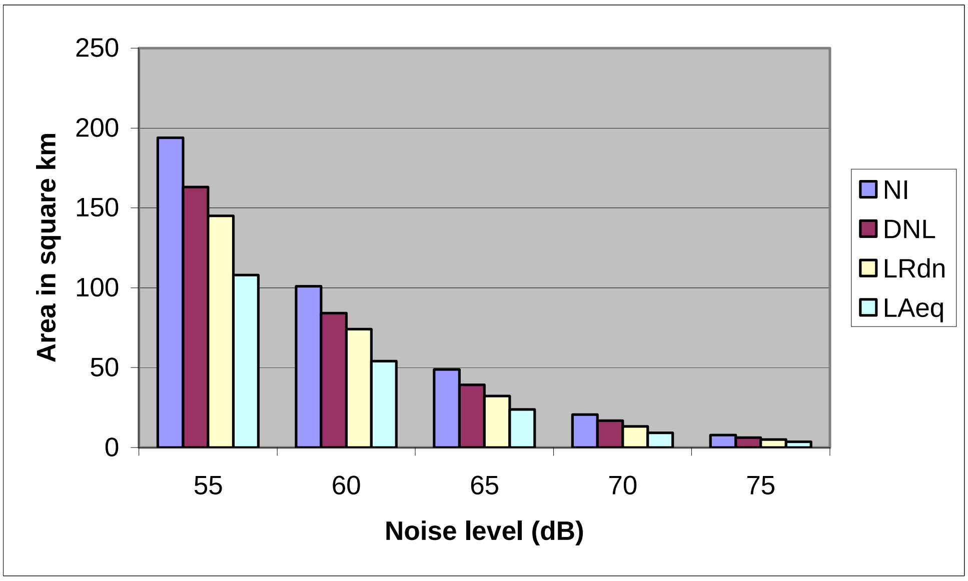


Figure 3.5: Comparison of the spatial extent of NI, L_{Rdn}, DNL and L_{Aeq} noise metrics

3.2 O.R. TAMBO INTERNATIONAL AIRPORT AND SURROUNDING NEIGHBOURHOODS AS STUDY AREA

OR Tambo International Airport was selected as a good representative example of a large international airport which has exhibited consistent growth in air traffic movements over time. It is South Africa's busiest airport with 161 526 air traffic movements and about 14 million passengers in 2004 (Airports Company South Africa 2006). While the airport is located in the Ekurhuleni Metropolitan Municipality between Kempton Park and Benoni (Figure 1.1) it serves a polycentric city in the central Witwatersrand made up of Ekurhuleni, Emfuleni, Johannesburg, Midvaal, Mogale City, and Tshwane[4] which together have a combined population of over 8 million (Pillay, Tomlinson & du Toit 2006).

The airport infrastructure itself has undergone considerable growth, particularly since South Africa's transition to a democracy in 1994, and this growth is set to continue. Between 1996 and 2001 the population of the surrounding urban areas also grew fast: Ekurhuleni by 22.4%, Johannesburg by 22.2%, and Tshwane by 18.0% (Pillay, Tomlinson & du Toit 2006). ORTIA operates international and domestic terminals and has a dedicated freight area. As of 2007, the Airport is undergoing an R11-billion upgrade to accommodate the new Airbus A380 aircraft, a station for the Gautrain, a new hotel, an additional parkade for 5 000 cars, and a new central terminal to link the domestic and international terminals. In the long term, a new terminal complex is planned to be built in the midfield between the two runways (Smillie, 2006) and new runway developments designed to cope with, and facilitate increases in air traffic movements are being considered (Geldenhuys 2006). The airport is also central to the Gauteng provincial government's plans to develop the province into a city-province (Gauteng Provincial Government 2006).

All of this means that as the airport infrastructure grows, more aircraft movements will be accommodated. In the absence of as yet undeveloped new technology which will reduce aircraft noise, it is probable that more noise from aircraft will be experienced in the surrounding neighbourhoods in the future.

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[4] List of changes to place names:

Old Name	**New name**
Johannesburg International Airport	O.R. Tambo International Airport
East Rand	Ekurhuleni
Vaal	Emfuleni
Vaal Triangle	Midvaal
West Rand	Mogale City
Pretoria	Tshwane

The airport's owner, ACSA, recognizes the impact of aviation on the environment:

> "As a responsible corporate citizen, ACSA has over the last three or so years intensified its research efforts and participated in various environmental studies and subsequent policy frameworks. Through these interactions, the company found that there was substantial interest around the issue of noise pollution." (Makgale 2006: no page number).

The airport has taken the initiative in advance to establish an Airport Environmental Committee as envisaged in the Department of Transport's *White paper on national civil aviation policy* (South Africa 2005). This committee meets regularly and is the vehicle to take the initiative for considering and implementing possible noise abatement procedures and noise mitigation measures. As yet the airport has not installed an automated, computer-based aircraft noise and track information system as has been done at many of the world's large international airports. However, the airport has a help desk which logs noise complaints and forwards them to the relevant personnel to investigate the grievance and suggest mitigation measures.

The airport recommends that noise abatement procedures (as published in the South African Aeronautical Information Publication) are adhered to by aircraft operators. There are no restrictions placed on times of operation (curfews), number of movements or aircraft types. Neither are there fines or penalties applied to aircraft exceeding limits as there are no limits in place.

With the inevitable increase in noise as a result of the expected air traffic growth, the question which arises is what residents living near the airport think about the noise impact. The noise contours described in Sections 3.1.1 to 3.1.4 were principally used to identify the noise impacted neighbourhoods and the study area around the airport namely Benoni, Kempton Park and Tembisa. In the next section the capture and manipulation of the survey data and aircraft operational data are dealt with.

3.3 SURVEY OF CITIZENS' PERCEPTIONS OF EVENING AND NIGHT-TIME AIRCRAFT NOISE

The rationale for a survey usually originates when there is a need for information because existing data are insufficient. No information could be found on the perception people in South Africa have of evening and night-time aircraft noise and so a survey was undertaken. A sample was used rather than undertaking a complete census for reasons of practicality and cost.

The survey was intended to evaluate the reaction of people who live in the vicinity of the airport, to aircraft noise. The main benefit of this survey for the researcher is the identification of broad trends in people's responses to noise from aircraft. Hoggart, Lees & Davies (2002) are of the opinion that a survey is a trawling exercise, designed to establish general trends, but lack the capability to reveal meaning and significance. This is a valid point, particularly in the present research since the response of people to aircraft noise is so varied (van Kampen 2005). It is important to keep in mind that any statistical results can only be applied with limited success in practice, as human behaviour – in this case response to aircraft noise – cannot be fully explained or predicted by statistical models.

In the present research, one of the primary weaknesses of surveys (at one level) – the communicative competence of the informant – is recognised, but the potential of the survey instrument to highlight incidences and trends is powerful. To do this meant establishing what data would be needed before undertaking the survey. It would be inefficient to conduct a survey if suitable data from other sources already existed – however, it was soon established that although many surveys of people's response to aircraft noise have been done overseas, this was not the case in South Africa.

Primary data are collected by a researcher to meet the specific objectives of a project (Sheskin 1985; Haining 2003). In the present study, the required primary data originated from the sample survey, namely resident's annoyance with evening and night-time aircraft noise, and interference with certain key activities carried out in the home.

The data recorded came from a set of fixed locations, the attributes measured being categorical. Such categorical data may be divided into parcels or blocks (Haining 2003). Instead of being called blocks, the land around the airport was divided into zones and the noise value recorded for each of these. The survey respondents, once geographically referenced, are points in geographic space. Each individual respondent was first assigned to a geographic location, and then to a noise zone.

Residential areas are places people normally return to in the evening and at night. Because aircraft noise is most disruptive to people when they are at home in the evening or at night, watching television, talking on the telephone, trying to work, study, or sleep, the key variables assessed in the survey were: annoyance (what people's general feelings about airport noise are); interference (sleep disturbance, telephone conversations, TV viewing, work or study); whether people would consider moving from the neighbourhood because of night-time aircraft noise; and what people's general feelings about aircraft noise are (after Blitch 1976; Brooker, Critchley, Monkman & Richmond 1985; Berglund, Lindvall & Nordim 1990; Fastl & Widman 1990; Staples, Cornelius & Gibbs 1999; Aasvang & Engdahl 2001).

To elicit information about noise disturbance from aircraft operations, a questionnaire was designed to explore the perceptions that communities around ORTIA have of aircraft noise. This is a modified version of the mail out/mail back procedure discussed by Sheskin (1985) and the American Statistical Association (1997). Sheskin (1985) and Hoggart, Lees & Davies (2002) outline a number of procedures which may be used to collect data. These include the personal interview survey, the intercept survey, mail surveys, telephone surveys and the most recent type of survey, the online survey. Dual survey mechanisms which combine any of these may also be used. The decision which then had to be taken was to select the method most likely to serve the purpose of the study. Two methods were chosen. Firstly, a drop-off and mail-back self administered survey was selected as being the best option for obtaining the required information in Kempton Park and Benoni. In Tembisa the intercept survey method was selected. The methods are discussed in detail in Section 3.6.1.

3.3.1 Survey design and execution

Two types of time critical data were collected, which referenced a specific time period of one week – an aircraft noise perception survey based on one week of aircraft movements, and the actual aircraft movements during the week of the survey. In this section the survey design and execution is discussed. Aircraft flight operational data is further discussed in Section 3.8.

A number of aircraft noise surveys were studied to determine what questions should be asked (Brooker et al 1985, Heinonen-Guzejev et al 2000, Health Canada 2001, Hiramatsu et.al. 2002, Miyakita et al 2002, Hume et.al 2003, Schipper, Rietveld & Nijkamp 2003). In these surveys, the researchers wanted to measure how individuals feel or think about aircraft noise. Neuman (2006) refers to these feelings or thoughts as the potency of feelings. In the present survey, annoyance and interference were the two key concepts being measured along with querying whether the respondent would consider moving away. The questions which were decided upon were determined by important aspects of people's lives affected by aircraft noise. The survey was softened to reduce bias – titled a neighborhood quality survey so as not to alert respondents immediately that aircraft noise disturbance information was being sought (Staples, Cornelius & Gibbs 1999; Utts 1996).

The survey was designed as an investigation to establish whether there is a functional relationship between aircraft noise and annoyance and activity disturbance in the time period between 18:00 and 06:00 i.e. evening and night (after Torgerson 1970). The survey was designed with closed-response questions, the data reflecting the researcher's prior structuring of the 'universe' (after Swift 1996).

In planning the survey, individual residents and other community members (former school principal, university students, chairman of a residents association), were approached with the aim of finding out if, and what aircraft noise concerns they had. A trial survey was then undertaken in the week of September 20th to 26th 2004 to check the credibility of the survey. Hoggart, Lees & Davies (1998) suggest that to get a feel for the problem investigated, the pilot group of respondents could vary from 5 to 50 respondents while Fink & Kosecoff (1998) suggest that the pilot survey may be stopped once it no longer yields any more useful information that helps improve the study. Questionnaires were dropped off at 30 residential addresses which lay directly under or very close to flight tracks observed in the field by the author to have regular aircraft movements. Respondents were invited to complete the questionnaire and return it by post in the pre-addressed and stamped envelope. The questionnaire was anonymous in order to encourage frank and honest views.

Once the pilot survey responses were returned, the proposed instrument was challenged so that it could be adjusted for better effect (Fink & Kosecoff 1998). The questions which were included in the pilot survey were included to focus on their clarity and see if they were understood. Six responses were received giving a response rate of 20%. These responses were examined to investigate whether the survey instrument could be improved. The closed-response questions (1 to 11) where respondents had to make a choice, for example between a range of phrases from 'very often' to 'never', were well answered with most respondents completing these sections. Question 1, 6, 8 and 9 were retained. Question 4 was adjusted for better effect, to give respondents more choice than a simple 'yes' or 'no' answer. For two reasons it was decided that questions 2, 3, 5, 7, 10 and 11 could be omitted. Firstly, they comprised questions which were not essential for the goals of this study; namely to investigating interference and annoyance caused by aircraft noise. Secondly, if the time required by respondents to complete the survey could be shortened, the response rate could be improved. The three open-response items were very poorly answered, the responses not being of any value. It was evident to the researcher that the respondents were willing to participate in a survey with closed-response questions and that open-response questions were to be avoided. This aspect of the pilot survey was particularly worthwhile, and the open-response questions were dropped.

Although not directly evident from the pilot survey, the author decided to use both the English and Afrikaans language in the final survey. This decision was taken to promote a feeling of inclusivity and improve the response rate.

The final improved survey materials used, viz. letter of introduction, questionnaire, and reminder letter are appended in Appendix A.

3.3.2 Questionnaire survey data capture

The data capture of survey responses was separated into neighbourhood quality and noise, and respondents' biographical information. Eight questions probed respondent's perceptions of their neighbourhood and the occurrence of aircraft noise (see Appendix A). The coded answers were captured into a spreadsheet for later analysis.

- Question one (concerning rating the neighbourhood overall as a place to live) required respondents to make a choice between Very good, Fairly good, Average, Fairly bad and Very bad. These answers were coded as 1 – 5 respectively.

- Question two requested respondents to indicate which noises they experienced in the neighbourhood. The choice of responses available to respondents for this question ranged from 'Very often' through 'Often', 'Sometimes', 'Seldom' to 'Never'. These answers were also coded as 1 – 5 respectively.

- Question three requested respondents to indicate whether 'Sleep', 'Telephone conversations', 'Television viewing', 'Work or study' and 'Other' activities were disturbed. The choice of responses available to respondents for these questions ranged from 'Very often' through 'Often', 'Sometimes', 'Seldom' to 'Never'. These answers were also coded as 1 – 5 respectively.

- Question four required respondents to answer 'Yes' or 'No' to the question on whether they would consider moving from this neighbourhood because of aircraft noise. These answers were coded as 1 & 2 respectively.

- Question five required the respondents to describe their general feelings about night-time aircraft noise by indicating whether they felt 'Highly annoyed', 'Considerably annoyed', 'Moderately annoyed', 'Slightly annoyed' or 'Not at all annoyed'. This question was also coded from 1 – 5.

3.3.3 Land-use information

Land-use information to be used as a backdrop for the noise contours and to orientate the reader was required. For better clarity, a combination of georeferenced 1:50 000 topographical maps and ESRI shape files were selected. This data was used to create maps to provide a backdrop against which the position of the noise contours and the locations of the survey respondents could be visualized. This information was also essential to visualise and assist with selecting the sample frame.

3.4 SURVEY SAMPLING FRAME

3.4.1 Runway layout and flight tracks

In order to make decisions on the survey frame, it is necessary to understand the layout of ORTIA’s runways and associated aircraft flight tracks (Figure 3.6). The airport has two parallel runways which are orientated at about 15 degrees east of true north and run to 195 degrees east of true north. The western runway has a length of 4 418m and the eastern runway is 3 400m long. To improve air traffic flow, and owing to its additional length, the western runway is generally used for departures and the eastern runway for landings.

To avoid confusion, and for safety reasons, runways are named after the magnetic compass heading they point towards. Compass headings can be any number from 0 to 359 degrees, so runways are referred to by the compass heading, but the last digit is dropped. For example, at ORTIA, the runways are referred to as 03 left, 03 right, 21 left and 21 right. The runways are spaced about 2.5km apart. Due to the busy nature of the airport, prescribed procedural departure and arrival flight tracks have been designed. The flight tracks are known as Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs). Aircraft flight crews are required to adhere to these procedures although exceptions may be made, visibility and other traffic permitting.

The SIDs and STARs for the airport were overlaid onto the appropriate 1:50 000 topographical maps and examined to obtain a broad visualization of where aircraft are routed. The standard route for flights departing from the airport is to remain on the runway heading until the first navigation point is reached. At this point the aircraft may commence with their initial turn to their intended destination. Arriving aircraft are stabilised on their approach at about 18km from their touchdown point.

It then follows that the sample frame would be located in the vicinity of these flight tracks.

3.4.2 The sample frame

Prior to selecting the sample, it is necessary to define the population to which inference will be made (Sheskin 1985). Selecting the sample frame can imply a certain ambiguity (Smit 1995) and this research reflected Smit's writing. The phenomenon of airport noise in a defined time period of one week was being investigated. It was therefore a prerequisite to know where the noise is, before its impact could be determined. However, the survey was limited to a specific time period of one week during which noise from aircraft would have been made. Therefore another way had to be found to determine the survey frame.

The sampling frame is best described as a modified probability sample after Hazard (1971). An experimental population and a control population were required. The experimental population had to be located in the vicinity of the airport's flight paths where there was a likelihood that they would be exposed to noise from aircraft operations. The control population were required to be located a similar distance from the airport but not directly under the flight paths.

The following were used to locate the sample frame:

- Firstly, the noise contour examples (Figures 3.1 to 3.4) overlaid onto a 1:50 000 scale topographical land-use map were examined to see which areas were affected at the time these noise contours were produced.
- Secondly, the published SID and STAR flight procedures were studied to understand where aircraft were expected to fly. Generally, for departures aircraft follow the extended runway centerline for about 9.4km from the start of the takeoff roll before turning on track. Arriving aircraft are usually

stabilized and on their landing flight track within about 18km from the runway touchdown point.

- Thirdly, field observations were made of aircraft flying into and out of the airport, to verify the SIDs and STARs. The writer drove into the suburbs and spent time observing the aircraft as they took off and landed. The general positions of the flight tracks were recorded on a map.
- Fourthly, the air traffic control centre was visited, and radar plots of aircraft flight tracks observed and examined. A computer linked to the radar network and an associated software distance measuring tool, was used to assess where aircraft were being operated and to validate the SIDs and STARs.

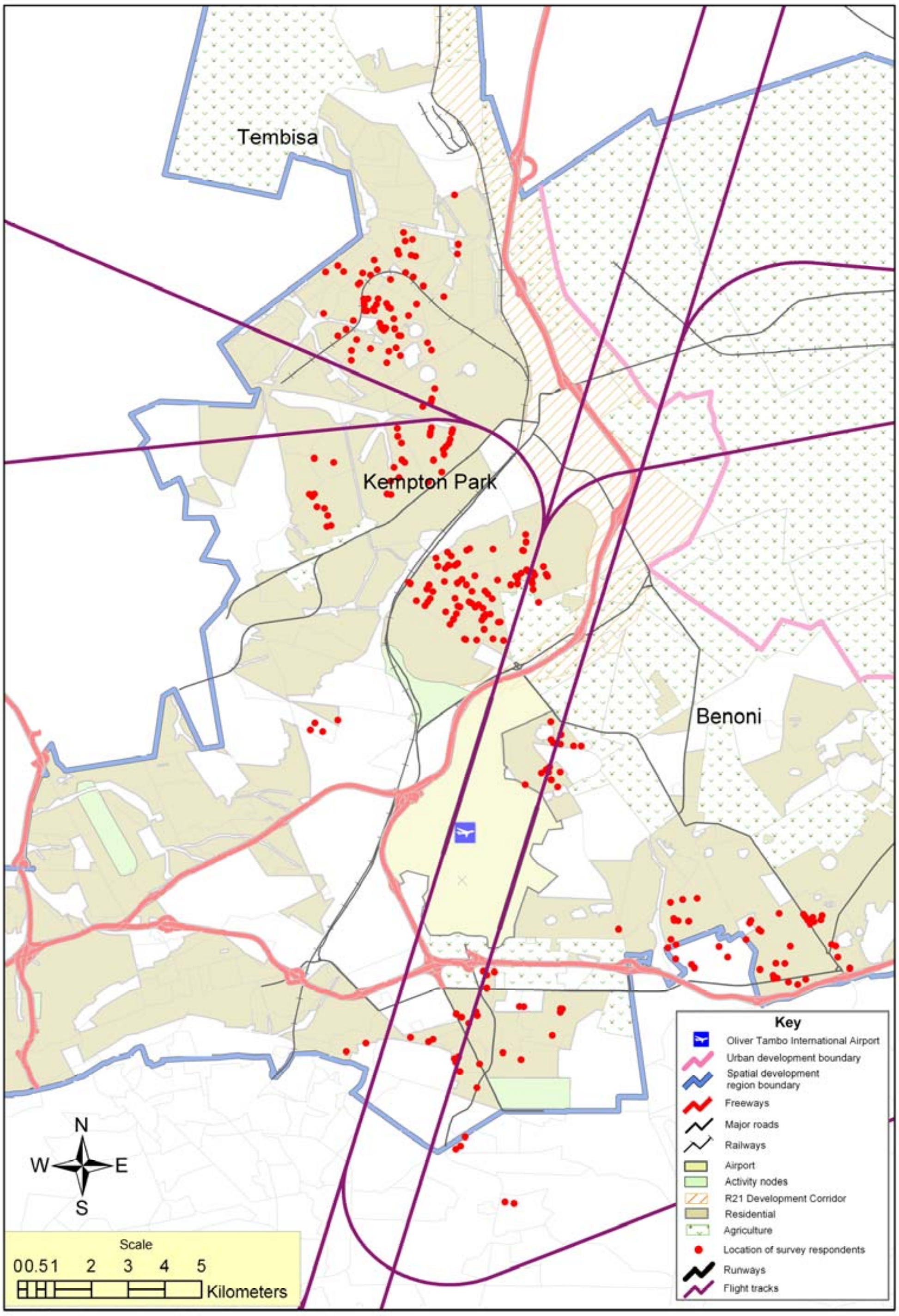
Although there are published flight routes, it was obvious from observation of flights and radar data that aircraft do not follow 'railway tracks' in the sky. Rather, the flight paths could be described as corridors in the sky within which pilots are expected to fly their aircraft. Once the flight paths were established, a cluster sample method was selected because a sample frame listing population elements was not available (Schofield 1996). There was the risk that the clusters would fall by chance on streets that were unrepresentative, either totally or to some extent. This risk was judged against the results - control group against the suburb group, (p value >.0001) and male/female respondent proportions (as judged against population census data) and deemed acceptable.

3.4.2.1 Age of respondents

Any adult over the age of 18 years in the household could be selected. Persons over 18 years should have had no difficulty in understanding the language and requirements of the survey which were designed to be comprehensible to anybody who has completed a primary school education.

3.4.2.2 Linking with Ekhuruleni's future planning

Because of the researcher's interest in Ekhuruleni's Northern Spatial Development Region (NSDR), and because of planned and potential development in this region, it was decided to concentrate on the land covered by this region. In Figure 3.6 the



Source: compiled by author

Figure 3.6: Delimitation of the study area: flight tracks and survey respondent locations.

Spatial Development Boundary region (shown in blue) to the west and south of the airport partially defines the study area. The Urban Development Boundary (UDB) to the north east defines the rest of the study area. The UDB (represented by a pink line) is the area beyond which no further urban development is to be permitted – in this instance to the east of the UDB as portrayed in Figure 3.6.

3.4.3 Selection of the respondents

Foster (1996) and Newman & Benz (1998) state that if a researcher's conclusion is supported by data from other sources, then they can be more confident of its validity. Phrased another way, was there a shared reality? Triangulation is a concept which expresses the idea that data should be collected in as many different ways and from as many sources as possible, the hope being that the data from different sources tells a similar story (Riley 1990, Foster 1996, Newman & Benz 1998). In the present study, the results will be compared with international results, whilst within the study, two survey areas will be assessed namely residential suburbs, and a township.

An experiment group (subdivided into two groups) and a control group were selected.

Figure 3.7 Residences in the control group area, Benoni

The requirements for the control group were (i) to consist of houses of similar construction, type and materials (Figure 3.7) to the experiment group (Figure 3.8 and Figure 3.9), and (ii) to be located at similar distances from the airport, but the control group not lying directly under flight paths.

Figure 3.8: Residences in the experiment group area, Kempton Park. Note the Boeing 777 visible above the houses

The control group's function is to evaluate whether in fact there is a difference between the experiment group in response to aircraft noise. The experiment group was divided into township respondents and suburb respondents. The construction of the type of dwellings in the suburb experiment group (Figure 3.8) differs from the type of dwellings in the township experiment group (Figure 3.9).

Figure 3.9 Houses in the township experiment area, Tembisa

The control group is located to the east of the airport. The houses in this group closely resemble the houses in the suburb group. No similar control group could however be identified to compare with the township group at a similar distance from the airport. This presented two choices – either omit the results from the township group or include them with an indication that no comparison was made, but that results could be obtained which may inform later research.

There are more residential areas to the north of the airport than to the south which is mostly mining land and industry. To the northeast and east of the airport, land is generally agricultural smallholdings, or plots with a low population density (see Figure 3.6, to the east of the pink UDB line). A field visit established that it would be very time-consuming and expensive to obtain information from residents in the smallholdings. None of the smallholdings had mailboxes which meant that delivering the survey was impractical, and the low density of residential properties would have made the survey cost-ineffective.

The survey frame was therefore identified in the north to be the Kempton Park suburbs and Tembisa township, and Boksburg suburb in the south. Both the suburb and township populations were selected on the cluster sample principle.

3.4.3.1 The selected suburbs

The first level of cluster selection was suburbs likely to be affected; the second level of cluster selected was alternative streets in an affected suburb; and the third level was every second house on the evenly numbered side of the street. This was seen to be a form of cluster sampling with the advantage of having a realistic element of randomness and reduced costs, but with the disadvantage of increased sampling error (Federer 1973; Foster 1996). These groups were located between 4.4km and 11.6km from the centre of the airport property, and roughly in line with the extended centerline of the runway system or within about 6km of the extended centerline. For the questionnaire delivery, a drop-off and post back method was followed in these suburbs.

3.4.3.2 Tembisa township

The township of Tembisa (northwest of ORTIA) was identified to be on the boundary of the noise contours. It was important to obtain the views of the township population for the purposes of triangulation of the results.

For the Tembisa survey the interview method was selected and interviewers used the intercept interview method of contacting respondents. The interviewers approached residents and asked them the questions from the questionnaire. Because language and literacy were barriers, interviewers were trained to administer the questions in a neutral manner and to obtain respondents' responses only.

Seventy interview surveys were conducted in Tembisa. The same questionnaire was used for Tembisa residents as for the suburbs. Two researchers were trained to administer the survey. Part of this training included the firm requirement that the researchers take great care not to introduce any bias into the answers. They were instructed to ask the questions and record a respondent's response as given.

3.4.3.3 The control group

The control frame was selected on the same criteria as the experiment groups with the exception that this group was not near the flight paths. The flight path criteria was replaced by selecting the control population in suburbs to the east of the airport at approximately the same range of distances of between 5km and 11.5km east of the centre of the airport property, but off to the east, in Benoni. This population's residences are not overflown by arriving or departing aircraft.

3.4.4 Time-frame of the survey

There were two time-related aspects to the survey. Firstly, the time period selected was the evening and night from 18:00 to 06:00 when respondents were most likely to be at home and their geographical location could be fairly accurately established. Secondly, the duration of the survey was selected to be one week. This was done to improve the chances of accurate recollection of noise events by respondents. This meant that participants would be responding to aircraft noise events when they were at home in the evening and at night for seven days.

3.4.5 Survey ethics

Questionnaires were answered anonymously. No information was requested which could be used to directly identify the respondents. Respondents were encouraged to feel free to express their opinions honestly and not fear being associated with an opinion. Residents were invited to participate and the covering letter made it clear that participation was voluntary.

IsiZulu, Afrikaans, English, Sepedi and Sesotho are the local languages mostly spoken in the study area (Ekurhuleni Metropolitan Municipality 2003a). A covering letter written in English and Afrikaans explaining the aims of the survey and what was required of the respondents accompanied each questionnaire. Tembisa residents who did not speak English or Afrikaans had the survey explained to them by the interviewer in one of the indigenous African languages.

3.4.6 Improving the survey response

A number of measures were implemented to improve the survey response rate. Firstly, a covering letter (in English and Afrikaans) introducing the researcher and explaining that a neighbourhood quality survey was being conducted was included (copy in Appendix A). English and Afrikaans language instructions were provided (see Appendix A). The name, institutional affiliation and contact details of the researcher were included so that respondents could contact the researcher if necessary. Secondly, an addressed, stamped envelope was included with each survey pack for easy return. Thirdly, a reminder letter (see Appendix A) was dropped off at every address at the end of the survey week to encourage participants to complete and post the questionnaire form back. Fourthly, the survey wording was kept simple and concise to encourage participation. The time required to complete the survey was stated to be no more than ten minutes, thereby indicating to participants that they would not waste their time.

3.5 AIRCRAFT FLIGHT OPERATIONAL DATA

For the success of the study it was essential to gather accurate aircraft flight information for the time period of the survey. The air traffic control authorities collect and store detailed information about the movement of aircraft, and their co-operation was sought in this regard. Much of the information which is gathered by air traffic control was not relevant to nor required for the present study, for example airline name and aircraft registration. The relevant information was extracted and supplied, namely the aircraft type, flight origin or destination and routing used, runway used, and time of flight.

The flight information was next prepared for capture into the Integrated Noise Model computerised noise modelling software. This entailed grouping the flight operations by aircraft type, operation type (arrival or departure), flight profile (used to estimate aircraft weight based on fuel uploaded for the distance of the flight), runway, flight track and time of operation. Because the flight operations had to be classified according to two time periods for survey analysis, namely an average 24-hour day (according to the requirements of South African National Standard 10117), and a 12-hour evening and night (18:00 to 06:00) period (required as part of the supplemental noise analysis), the flight grouping will be discussed next.

3.5.1 24-hour flight operation data

Aircraft movement data was captured into a spreadsheet and sorted as described above. Air traffic control records store the time of the flight according to Universal Time (UT) which is two hours behind South African Standard Time (SAST). SANS 10117 prescribes a weighting of 10dBA for flights between 22:00 and 06:00 SAST which is 20:00 and 04:00 UT. Care had to be taken to group all flights according to the correct SAST they operated to ensure that the correct noise weighting would be applied to the flight.

3.5.2 12-hour evening and night flight operation data

No weightings were applied to the flights operated in the evening and night period of 18:00 to 06:00 SAST. Nevertheless, similar to the 24-hour aircraft movement data, the aircraft movement spreadsheet was carefully sorted to enable accurate selection of those flights which took place between the required times of 18:00 and 06:00 SAST (16:00 and 04:00 UT) which corresponded to the times on the survey form for which respondents were required to provide information.

3.6 METEOROLOGICAL DATA

The INM requires average meteorological data to improve computational accuracy. They are temperature, humidity, pressure and wind speed. The average meteorological data for the study week were obtained from the airport's meteorological office.

3.7 DATA CAPTURING AND DATA EDITING

Two separate data flows had to be collected. Firstly the survey was administered for one week, and this data collected. Secondly, aircraft operational information for the same week of the survey was collected, and noise contours for these flight operations produced. A 24-hour L_{Rdn} contour representing flight operations of the survey week was produced. This contour represents the SANS 10117 methodology. Further, the following supplemental noise information was produced: a 12-hour contour representing operations from 18:00 to 06:00, and N60, N70 and N80 contours.

The survey data was prepared following the example of Swift (1996). As the survey contained closed questions, the respondents were forced to choose from one of a set of options designed to measure the intensity or potency of a variable (Neuman 2006). Numbers (codes) were assigned to the various answers on the questionnaire. Each returned questionnaire form was numbered and filed. The numbering was important for later location of the respondent's residence. The 5-point (Likert-type) scale questions were coded as were the questions where there was a simple yes/no answer. Biographical information was also coded. The data was captured onto a spreadsheet according to the codings.

In order to preserve the anonymity of the respondents, no information was requested which could be used to directly identify the respondents. However, the respondents were asked to indicate their street name, and nearest intersecting street. The numbered questionnaires were used to match the location of the respondent on a GIS as accurately as confidentiality would allow. The respondents' survey form were used to identify their suburb, street and nearest intersecting street in the GIS. An xy co-ordinate point was created with the respondent's survey attribute information attached.

3.8 Aircraft operations data.

The flight records discussed in Section 3.5 were used by the writer to set up the INM aircraft modelling computer software. Version 6.1 of the software was used and two types of noise contour were produced. The INM was used to generate a 24-hour L_{Rdn} contour and a 12-hour night L_{Aeq} contour. A grid file which was further input into the TNIP software was used to generate 12-hour N60, N70 and N80 contours. The INM noise contours and the TNIP contours were imported into the GIS.

3.8.1 Average energy contours: the Integrated Noise Model

Data was captured by the writer into the INM in a sequence which was grouped according to aircraft type, then runway, followed by operation type (arrival or departure), stage length (for departures, the distance of the flight), flight track, and finally number of day and night flights.

Two noise contours were required representing two noise descriptors namely a 24-hour L_{Rdn} and a 12-hour L_{Aeq}. In the INM, the menu item ‘setup metrics’ option was used to create these metrics. The L_{Rdn} option was set up with a ‘day’ period and a ‘night’ period with a weighting of 10. The evening and night L_{Aeq} was set up as an unweighted 12-hour L_{Aeq} metric.

The menu item ‘run’ was selected to instruct the software to calculate the noise contours from the input data. Once the calculations had been performed, the menu item ‘output graphics’ was selected and the required ESRI shape files generated.

3.8.2 Number of events contours: the Transparent Noise Information Package

The Transparent Noise Information Package (TNIP) is a computer application developed by the Australian Department of Transport and Regional Services (DOTARS). Its primary use is to enable the generation of aircraft noise information descriptors such as flight path movements, number of events above a specified level, and aircraft noise contours. It can also be used as a tool to ‘see inside’ noise contouring studies, and it is this capability which is applied in the present study.

In order for TNIP to run, a grid file which is generated by INM from the input data used to create the average energy contours must first be created. The grid file is then processed in TNIP to produce the number of events contour files. These contour files are then imported into the GIS for further analysis. To fulfil the aims of the study, the writer produced a set of three number-of-events contours, based on the aircraft operations data used to calculate the 12-hour evening and night L_{Aeq} contour. The three sets of number-of-events were:

- Number of events above 60dBA
- Number of events above 70dBA

- Number of events above 80dBA.

3.9 DATA ANALYSIS

An electronic map depicting the roads and suburbs of the study area was imported into a GIS. The address on each numbered survey form was located on the electronic GIS map, and a point created with the survey number as the attribute. This was followed by draping the five noise contours onto the map with the survey points. Noise zones were created and the survey points in each noise zone identified and classified. The GIS was queried and the survey locations falling into each of the noise zones of the five scenarios identified. The following noise zones in each of the five scenarios were used, namely

- For the average energy analysis
  24-hour <55, 56 – 60, 61 – 65, 66 – 70 and 71 – 75 L_{Rdn} noise zones
- For the supplemental noise analysis:
  12-hour night L_{Aeq}: <55, 56 – 60, 61 – 65, >66 L_{Aeq} noise zones
  12-hour night N60: <10 events, 10 – 20 events, 21 – 50 events, >50 events
  12-hour night N70: <10 events, 10 – 20 events, 21 – 50 events, >50 events
  12-hour night N80: <10 events, 10 – 20 events, 21 – 50 events, >50 events

Using a commercial statistical computer programme (SAS), the data were transformed to standard two-way tables for analysis.

3.9.1 Cross tabulations

Bivariate frequency distributions, or cross-tabulations, expressed in percentages rather than response frequencies form the main vehicle for the graphs used in Chapters 4 and 5 for presenting and examining the relationship between noise zones and the survey variables. The dependent variables are the survey responses being explained by the author, and the independent variables are the noise zones used to explain the survey responses. Two way tables were selected because they lend themselves to analysis of the relationship between the numbers inside the table and the row and column labels. Apart from these relationships, the numbers inside the table may exhibit an internal structure which is a matter of fundamental interest (Mandel 1995).

The chi-square test was used to test whether there is a difference between two samples of data expressed in frequency form. The control group and the suburb group were treated as a random cross-section of the population at large and also as two random samples for the purpose of the chi-square test. A large value of chi-square indicates that there is a large amount of difference between the observed and the expected frequencies (Ebdon 1977). The null hypothesis is that there is no difference between the control group and the suburb group in terms of annoyance and interference (with sleep, television viewing, telephone conversations and work or study) due to aircraft noise. A significance level of 0.0001 was chosen.

Amalgamation of categories can be used to overcome the problem of low expected frequencies (Ebdon 1977). In the case of the 12 hour average energy L_{Aeq} contour, the noise zones above 66 L_{Aeq} were combined because of the small size of the area delimited by the contours, and the low number of respondents in these zones.

3.10 SHORTCOMINGS AND SOURCES OF ERROR

To preserve the anonymity of the respondents, and therefore encourage frank responses, their physical addresses were not requested. Respondents were asked to indicate their street name and that of the nearest intersecting street. Since no suburban block runs for more than about 220metres without an intersection, the accuracy of respondent location is at this level. This means that respondents living close to a noise zone line may or may not be included.

It was left up to the household members to decide who would complete the survey form. Many factors could come into play in motivating respondents to participate, for example assertiveness or taking on a positive mental attitude after balancing the noise disturbance with the positive aspect of the airport being nearby (Hume et al. 2003) or older members of the household being more inclined to answer than the younger members.

Records of detailed radar flight tracks were not available. While aircraft are expected to follow the published flight routes, there may be instances where they do not, which consequently has an effect on the size and shape of the noise contours.

To conclude, this chapter has outlined how the observation component of this dissertation was conducted. Although the criticism can be made that the data are only a snapshot representing one week's worth of airport operations, it is pointed out that limiting the time frame facilitates better recall of noise events by respondents and from which more reliable conclusions may be drawn. In the next chapter, the average energy results are discussed.

CHAPTER 4: SURVEY RESULTS: INTERPRETED ACCORDING TO AVERAGE-ENERGY NOISE INFORMATION

Using statistics as a sort of shorthand summary of complex information is common (Dickinson 1973). If the procedure is to succeed though, the prerequisite is that the statistics used to represent conditions (ie aircraft noise disturbance) at a place really do so.

Statistics are a valuable source of information which can be used to create awareness and provide an understanding of the topic under consideration. When interpreting the results of this study, the variability of people's response to noise must be kept in mind (Abbott & Pivo 2000,). Annoyance is difficult to operationalise (Enmarker & Boman 2004), and so this study is to be regarded as a perception study. The answers to survey questions are based on perception, not empirically verifiable fact.

The noise contours are based on assumptions about aircraft flight tracks. Aircraft arriving or departing from the airport are instructed to follow specific routes. Although care was taken to ensure that these routes were replicated as accurately as possible, there could be discrepancies in aircraft flight tracks for air traffic control reasons. Air traffic controllers on duty during the study period were of the opinion that there were no reasons why such deviations would have occurred. The major reason for deviations is severe weather and this did not occur therefore the noise contours for this study can be accepted as true and accurate.

4.1 SPATIAL ANALYSIS OF THE DATA

The term spatial analysis has been used in geography since the 1950s (Berry & Marble 1968; Haining 2003) and is nowadays widely used in the GIS and geographical information science literature (Malone, Palmer, & Voigt 2002; Haining 2003). Spatial analysis represents a collection of techniques and models that explicitly use spatial referencing (Haining 2003). In the present study, noise zones constructed from individual noise points are associated with each survey point specified within the system under study.

The purpose of the analysis initially is to describe the spatial variation in attribute values across the study area. The next step is to explain the spatial pattern of variation in terms of the attributes. Interesting features in the data are identified, including detecting clusters or concentrations of high values, and the final step is to try and explain why there are concentrations of high values (Haining 2003).

In describing and explaining the variation in perceptions of airport noise across the noise zones the locations of respondents are treated as fixed. The survey responses are regarded as one dataset. The urban area around the airport is partitioned into five noise scenarios, each of which is subdivided into noise zones that have been defined independently of the distribution of the survey response sites. These five noise scenarios are regarded as five further datasets. The location of the five noise scenarios are regarded as fixed, according to the calculation methodology. In actual fact, aircraft noise exposure around the airport changes constantly as determined by aircraft movements. The noise contours are therefore a snapshot representing the period in time that they are based on.

Spatial data analysis can be considered a sub-field of the more general field of data analysis. Haining (2003) believes that spatial data analysis has three main elements which are used here. Firstly, it includes cartographic modelling. Each data set is represented as a map, and map-based operations generate new maps. Overlaying includes the generic logical operation .AND. which was used to identify areas on a map which simultaneously satisfy a set of conditions on two or more variables. For example the .AND. function was used to locate which of the respective noise zones the respondents lived in.

Secondly, spatial analysis includes forms of mathematical modelling where model outcomes are dependent on the form of spatial interaction between objects in the model, or spatial relationships or the geographical positioning of objects within the model. In this study, the land surface around the airport is divided into a grid. At each point on the grid, the noise is calculated for each aircraft operation. Each answer is added to a total, and the average noise level for each grid point is calculated.

Thirdly, spatial analysis includes the application of statistical techniques for the analysis of spatial data and which make use of spatial referencing in the data. Statistical graphics are a powerful system of visual communication of arrays of figures. They have two primary functions: presentation and analysis. Whether statistical charts are used for analysis or presentation, they serve as essential media for communication (Schmid 1983). For this reason the correct choice of graphic form should be selected. In judging the acceptability of a particular type of chart, consideration should be given to the nature of the data the chart is to represent. In this study, solid and subdivided column graphs are used.

The analysis of the results is broken down into a number of steps, proceeding from overall impressions, to groups and then noise zones. The analysis of the survey results will take place as follows:

- Firstly, the survey results will be interpreted overall in the first section of Chapter 4
- Secondly the survey average noise levels will be dealt with in the second section of Chapter 4.
- In Chapter 5, the survey results will be interpreted according to the supplemental noise information. (evening and night average energy noise contours, and number of events contours).

4.2 ASSESSMENT OF THE SURVEY

In this section an assessment of the survey data is presented.

4.2.1 Selection of valid questionnaires

Valid questionnaires were selected according to two criteria, namely

i) that the answer contained the name of the street where the respondent resides and the nearest intersecting street, so as to be able to identify the L_{Rdn} noise exposure zone, 12-hour evening and night L_{Aeq} noise exposure zone and N60, N70 and N80 number of events zones that the respondent resides in. This allowed geo-referencing of each respondent to be as precise as confidentiality would allow (Haining 2003), and

ii) that the respondent's age was 18 years or older, thus ensuring that youngsters who may not treat the survey responsibly had not participated. No questionnaires were rejected based on this criterion.

Table 4.1: provides a summary of the questionnaires sent out and responses received. The only reason not to use a survey response form was if the address was bad. A total of 880 survey forms were distributed and 329 valid responses returned meaning that just over one third of survey forms which were distributed were eventually used.

Table 4.1: Final response summary of the questionnaire survey of aircraft noise disturbance around OR Tambo International Airport.

	Number	Percentage
No usable response obtained by reason of bad address	14	1.6
No answer	537	61.02
Valid responses	329	37.4
Total	880	100.0

4.2.2 Questionnaires distributed and returned

Figure 4.1 illustrates the number of survey forms distributed and usable questionnaires received from each of the three groups. The highest number of returns came from the suburb group followed by the township group then the control group.

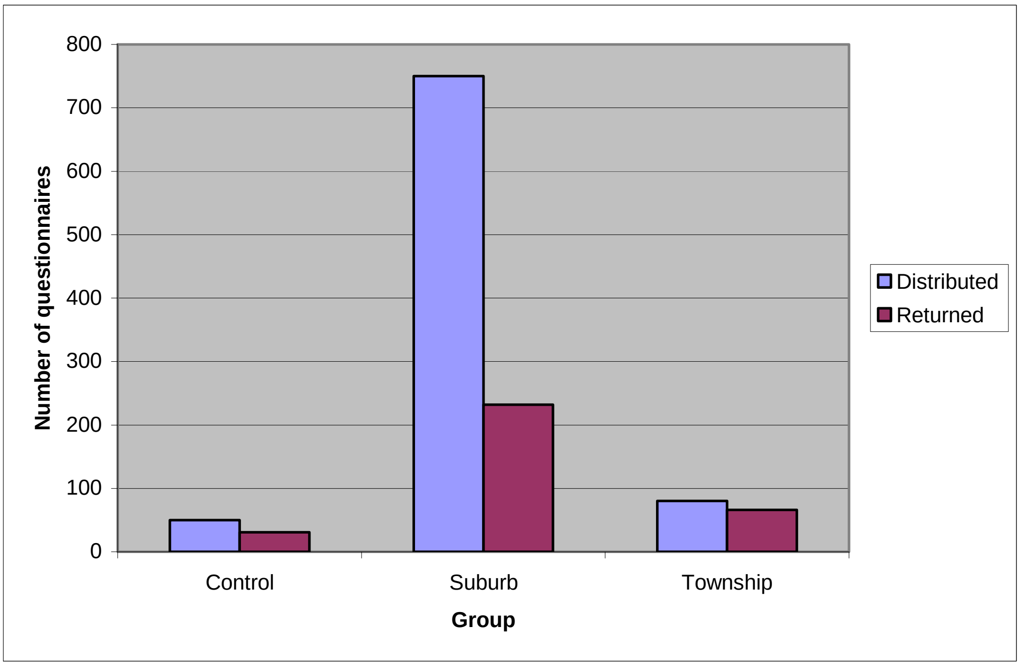


Figure 4.1: Number of questionnaires distributed and returned

In Figure 4.2 the number of questionnaires and percentage of questionnaires returned respectively are compared. The control group returned 62% of the survey forms, the suburb group 30.9%, and the township group 82.5%. The overall response rate of 37.4% was considered good. The township response is exceptionally high because another type of survey was conducted. The completion of the questionnaires was assisted by interviewers who communicated with respondents in their home languages. Sheskin (1985) and Schofield (1996) report that the response rates of drop and post-back surveys as used in the control and suburb groups are usually low unless the respondent’s interests are engaged and/or or the investigation is perceived to be of value to the respondent.

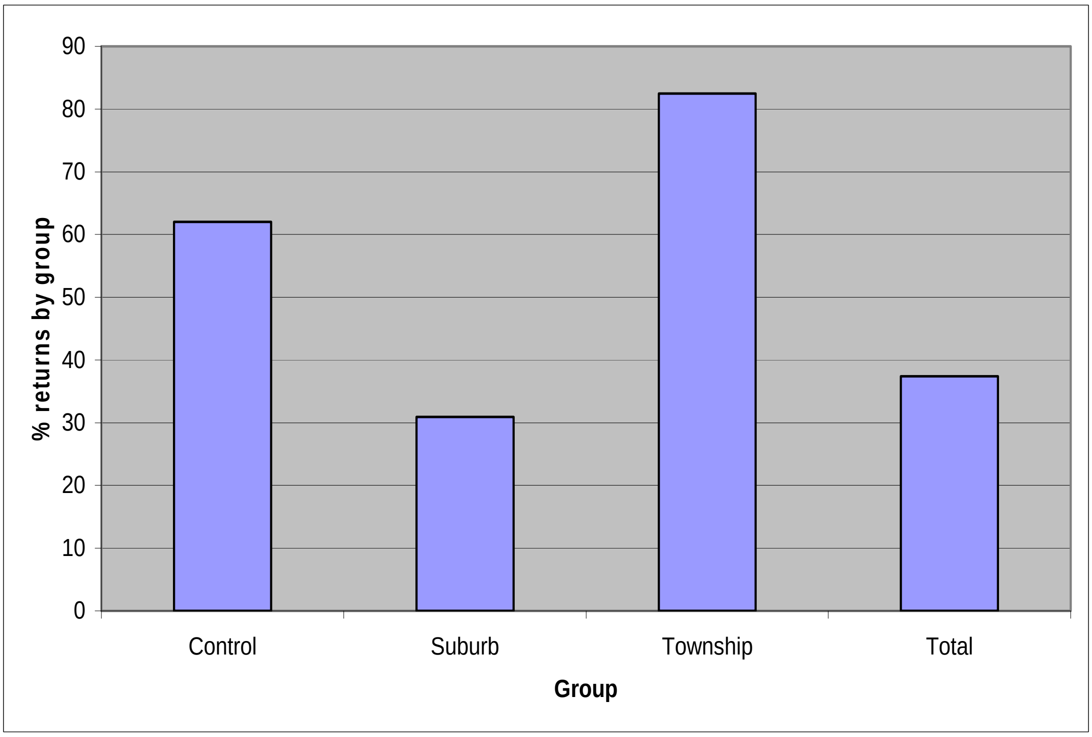


Figure 4.2 Percentage of questionnaires returned per sub-group, and the total percentage returned.

The acceptably high response rates of the suburb and control group subjects can be ascribed to the following suggestions adopted from Jenkins (1999) and Thomas (1999):

- All the survey materials were bilingual (English and Afrikaans) thereby giving the respondents a choice of language in which to respond,
- An addressed and stamped envelope was included for returning the questionnaire, thereby reducing cost and inconvenience to a respondent,
- A reminder in English and Afrikaans was dropped off at each sampled house at the end of the survey week,
- The time taken to complete the survey was quite short and an overload of information was not requested.

4.2.3 Gender

Respondent gender is not a condition for questionnaire acceptability. However, gender is an explanatory variable which will be discussed later, so the gender breakdown is given in Table 4.2. There were 13 responses without gender indicated. The gender proportion of respondents to census data is well correlated.

Table 4.2: Gender summary

Gender	Survey		Census
	Number	Percentage	Percentage
Male	161	50.9	50.7
Female	155	49.1	49.3
Total	316	100	100

4.3 REPORTED ANNOYANCE LEVELS

Respondents reporting high levels of annoyance to aircraft noise during the week of 16 to 22 October 2004 between 18:00 and 06:00 are shown in Figure 4.3 where it is clear that the experimental group reported a much greater level of annoyance (32.8%) to aircraft noise than the control group (3.2%). This result creates an initial impression that evening and night-time aircraft noise is a problem.

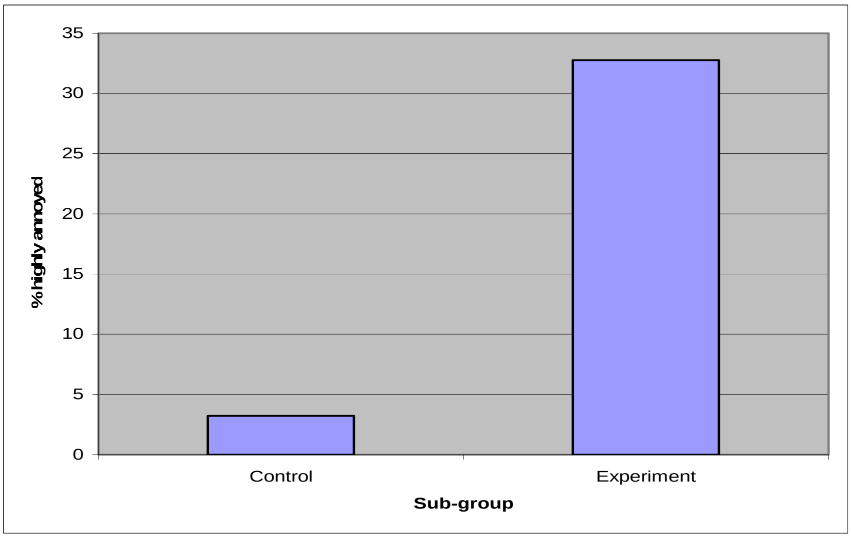


Figure 4.3: Control group and experiment group reporting being highly annoyed due to aircraft noise between 18:00 and 06:00.

It is important to also evaluate how often people hear aircraft noise as opposed to their degree of annoyance with noise. If the results had shown the people who never hear aircraft noise were highly annoyed, they would have been suspect. However, this was not the case. Figure 4.4 illustrates a clear link between the frequency aircraft noise is heard, and the degree of annoyance. Of respondents who heard aircraft noise very often, 58.6% reported being highly annoyed. Expectedly, 71.4% of residents who never hear aircraft noise reported not being annoyed and the remainder were only slightly or moderately annoyed. More than 90% of the respondents who seldom hear the aircraft are not annoyed at all.

As the frequency with which aircraft noise is heard increases, so the degree of annoyance increases. Considerable and high annoyance only occurs when noise is heard very often. Interestingly, respondents who seldom hear aircraft noise report being less annoyed than respondents who never hear aircraft noise.

This overall picture of noise frequency and respondent annoyance calls for disaggregation by sub-group, namely control, suburb and township in order to expose any inherent differences and similarities.

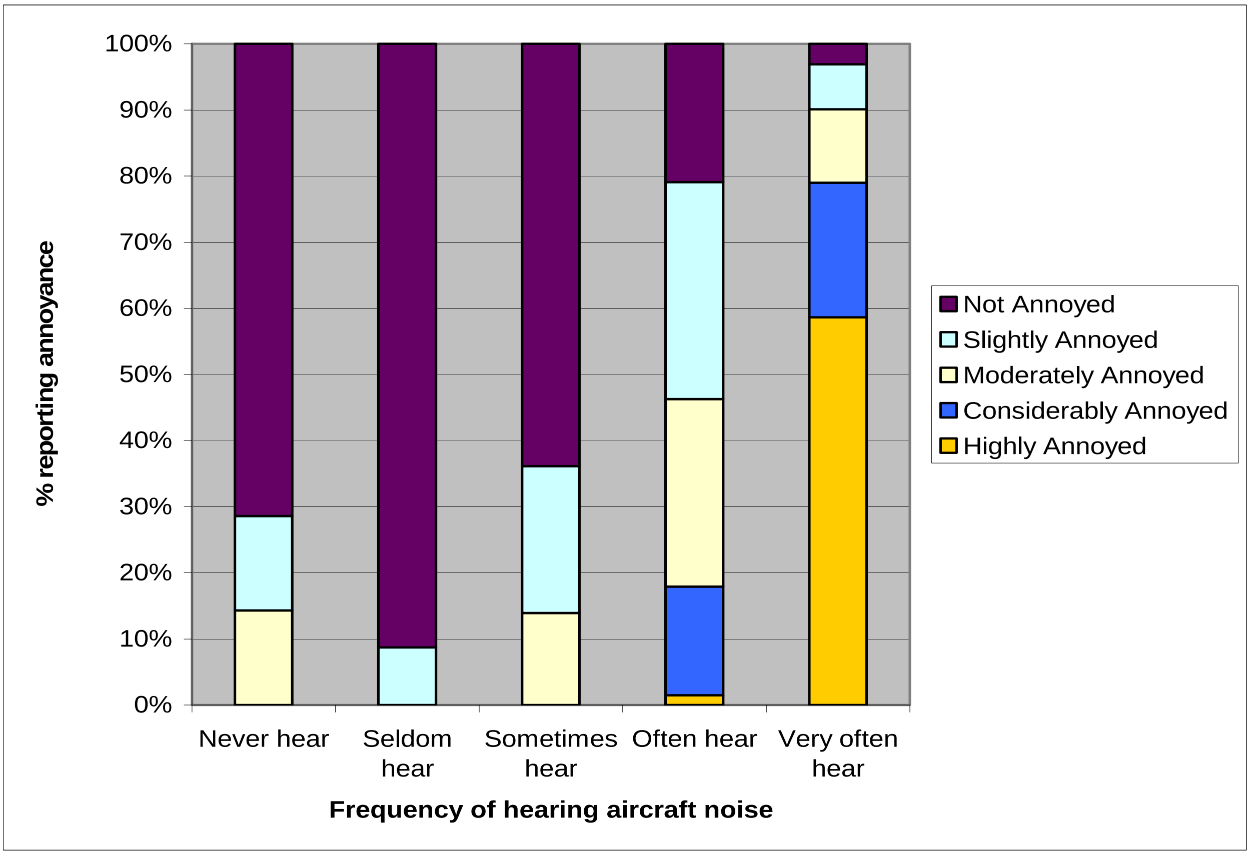


Figure 4.4: Degrees of annoyance reported according to frequency of hearing aircraft noise (all respondents)[5]

4.4 OVERALL ANNOYANCE BY THE CONTROL, SUBURB AND TOWNSHIP SUB-GROUPS.

In this section the data are disaggregated into three subgroups; namely control, suburb and township.

Figure 4.5 shows the differences in experiencing a high degree of annoyance between the three sub-groups. The houses and neighbourhood quality of the "suburbs" (as

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[5] The tables of data from which the graphs were drawn, and where relevant, the chi squared significance test results are included in Appendix B. The pattern will be followed of presenting first the figure number and title of the figure, then the table, then the chi squared significance test where appropriate.

illustrated in Figures 3.7 and 3.8) typical of the control and experiment groups respectively are quite similar. The control and experiment group are equidistant from the airport with the difference that the control group is not under the flight paths. The control group reported the lowest level of annoyance (3.2%). This was expected. On the other hand the township group reported the highest degree of annoyance due to aircraft noise (42.4%). A number of reasons are possible for the latter finding. Materials used in the construction of township houses offer less insulation from sound (see Figures 3.9 and 4.11). Further, there may be a general dissatisfaction with the neighbourhood, with residents behaving strategically (political maneuvering) in the hope that their voices be heard. Bias, introduced by the interviewers, is also possible.

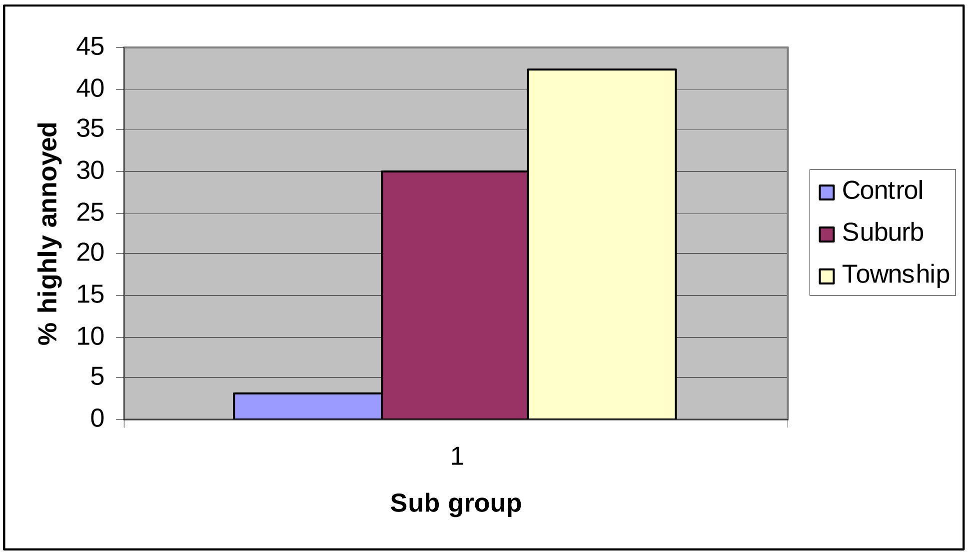


Figure 4.5: Sub-groups reporting being highly annoyed due to aircraft noise between 18:00 and 06:00

In the remainder of the analysis, the township group was separated from the suburb group for two reasons. Firstly, the method of survey delivery and collection differed, and secondly, it was apparent that the township group's responses were more strongly negatively biased. The negative responses seemed to be more intense and exaggerated than the suburb group (Figure 4.5). Of township respondents, 42.4% reported being highly annoyed compared to 30 % of suburb respondents who felt likewise. The township respondents live the farthest from the airport along the flight track which routes to the west of the airport. The aircraft have climbed higher when overflying Tembisa, implying that aircraft noise levels will be lower. However, many of the houses are also constructed of materials which do not provide much acoustic insulation against noise as is clearly evident in Figure 4.6.

Figure 4.6: Houses in Tembisa with little acoustic attenuation

Houses in the suburbs tend to be constructed from brick and mortar which are better at preventing noise from penetrating inside. It is assumed that residents would have been inside their houses when the survey was completed – four of the activities investigated reporting interference (sleep, television viewing, telephone conversations and work or study) would take place indoors. Some township houses are brick and mortar whilst others are made from whatever convenient materials are available. This may explain why township residents report more annoyance from noise. It is also possible that a bias may have been introduced by the survey collectors. The method of collection of survey data in the township group differed from the method of delivery of the suburb group. Although the assistants were instructed to be careful about injecting their own opinions into answers – they subsequently gave assurances that they adhered to this requirement – it is not possible to establish whether the responses are unbiased.

The township group's responses are important as Tembisa lies outside the noise contour usually considered as the limit for residential land-use planning ($55L_{Rdn}$).

Consequently the responses of the township group will be included in the following discussions, but will be considered separately.

The variation in response between the township group and the suburb group is difficult to account for. Several studies have investigated the relationship between level of impact and degree of annoyance, but they have not been able to establish a close relationship between them on an individual level (Voogd 2000). This difference in response could be the subject of a future investigation.

The degree of annoyance experienced by the three sub-groups is graphically illustrated in Figure 4.7.

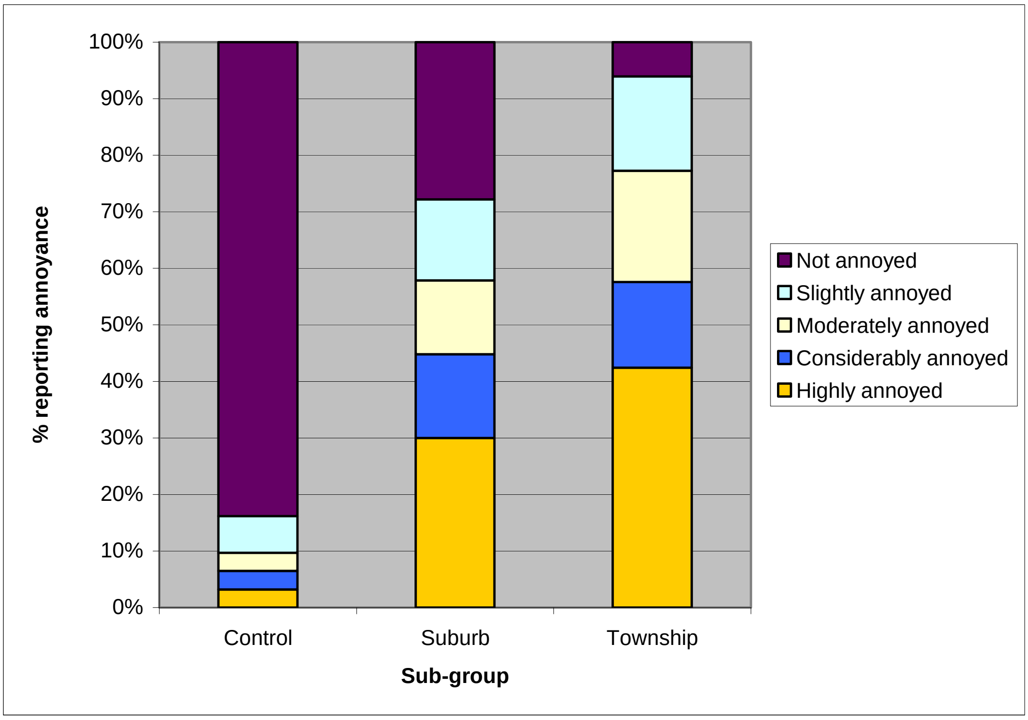


Figure 4.7: Degree of annoyance caused by aircraft noise between 18:00 and 06:00 according to respondents in the three sub-groups.

Of the control group, 83.9% reported not being annoyed at all – a result that was expected. It is, however, noteworthy that only 6.1% of township respondents reported no annoyance at all. This is an unexpected result because these residents lie outside of the 55L_{Rdn} contour which is presented in the recommendation for land-use planning in Table 2 of the Standards South Africa document SANS 10103: 2003. Significantly, 27.8% of the suburb residents – they live under the flight paths – reported not being annoyed at all.

In the case of the control group who are located near the airport, but not directly under any of the flight paths, a few (3.2%) reported being highly annoyed by aircraft noise. The aircraft noise these residents hear is probably caused by aircraft engines being tested late at night after maintenance. Less than one third of the suburb group which was located in the vicinity of flight paths, reported being highly annoyed by aircraft noise. The township group reported that 42% of the respondents were highly annoyed by aircraft noise.

If the township group is compared to the control group, then it may be considered odd that they report such high levels of annoyance whilst they are outside of the 55L_{Rdn} contour. On the other hand, the flight paths do lie in the vicinity of the township residents and it is probably the noise from the single events of flights using these tracks which causes the disturbance.

4.5 OVERALL ANNOYANCE ACCORDING TO GENDER

It was not expected that there would be a difference in annoyance levels between males and females. In Table 4.3 and Figure 4.8, the gender based reply to respondents being asked to describe their feelings about aircraft noise is given. Slightly more males (32.3%) than females (27.1%) reported being highly annoyed. Conversely, 32.9% of females and 25.5% of males reported no annoyance.

Table 4.3: Degrees of aircraft noise annoyance experienced by men and women respondents.

	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not annoyed
Female	27.1	12.3	14.8	12.9	32.9
Male	32.3	14.9	11.8	15.5	25.5
Total	59.4	27.2	26.6	28.4	58.4

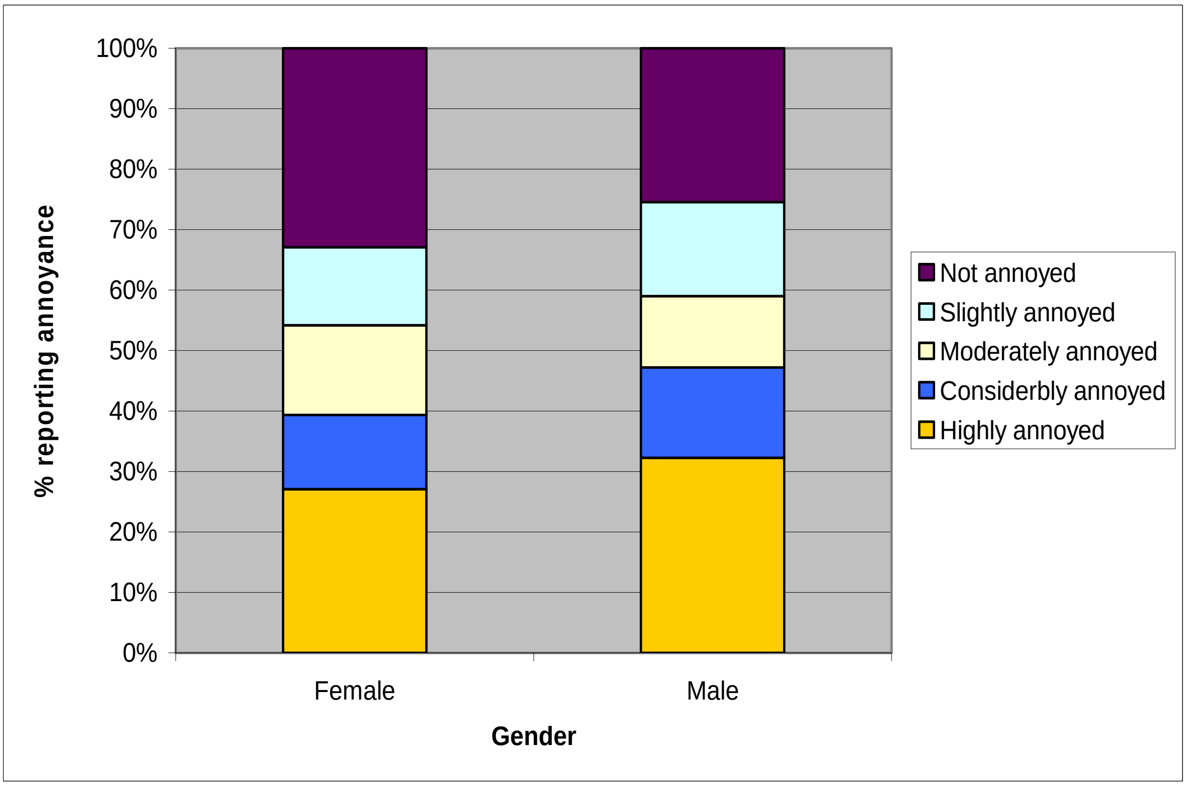


Figure 4.8: Female and male distribution of noise annoyance

4.6 AIRCRAFT NOISE INTERFERENCE WITH HOUSEHOLD ACTIVITIES

In addition to the analysis of annoyance, which is a general state of mind, four activities which take place at home were identified for analysis to see whether aircraft noise interferes with them. They were sleep, television viewing, telephone conversations, and work or study (the latter two were combined in the survey form). This section reports on the interference of aircraft noise on these activities as reported by the survey respondents.

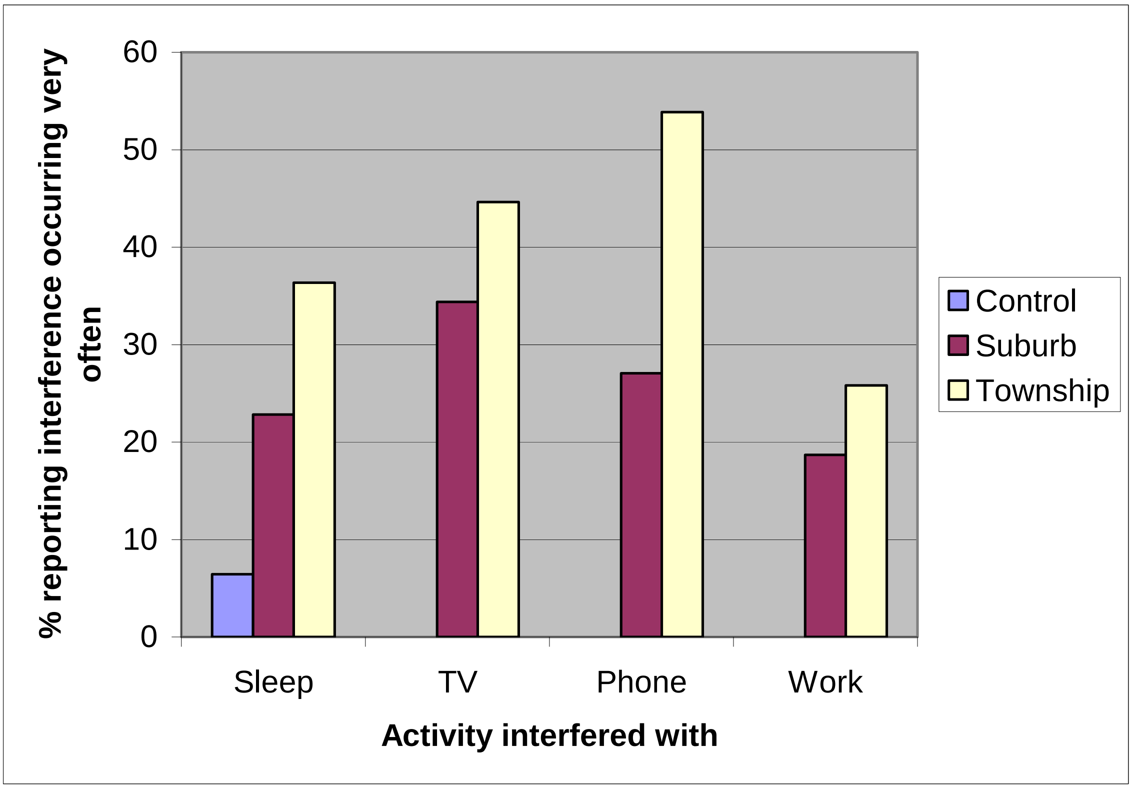


Figure 4.9: Percentage of responses about home activities being interfered with very often by aircraft noise.

About 6% of the control group reported that aircraft noise interferes with sleep (Figure 4.9) whereas no control group respondents reported that there was interference with their television watching, telephone conversations or work/study activities very often. Township residents reported the highest percentages of interference with sleep, television watching, telephone conversations and work/study. This is a significant finding as the township residents live outside the land-use planning contour where interference levels would be expected to be low. Telephone conversations were most interfered in the township, whilst suburb residents reported television viewing as being the most interfered with.

These findings confirm that the level of annoyance according to noise only is difficult to explain. Wagner (2000) reports that two thirds of the individual variance in the reaction to noise is dependent on individual traits and the surrounding environment. He gives an example of how in visually attractive streets residents feel less annoyed than in visually unpleasant streets with the same level of noise. Wallenius (2004) reports that physiological effects and health complaints are more closely related to subjective reactions to noise than to the noise itself.

Figure 4.10: A typical street scene in a suburb group

A typical street in the suburb group is illustrated in Figure 4.10 and a township street in Figure 4.11. Wagner's (2000) assertion that the visual attractiveness of the surrounding environment can have a bearing on aircraft noise perception can be understood when these two streets are compared. The peace and tranquillity suggested by the green leafy suburb is in stark contrast to the bleak barrenness of the township.

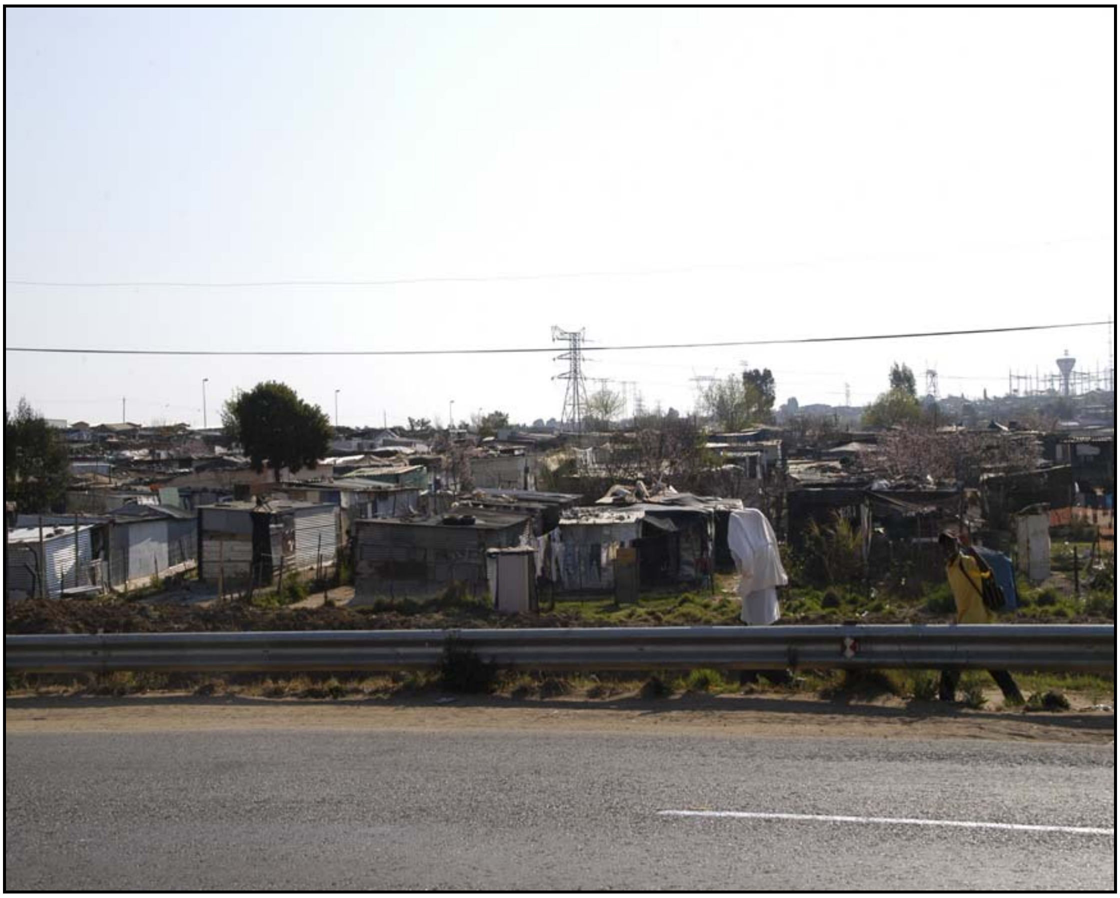


Figure 4.11 A typical street in Tembisa

4.7 AIRCRAFT NOISE AS A MOTIVE FOR MOVING AWAY

If the frequency of aircraft noise heard by residents is perceived to be too often, and annoyance by the noise becomes unbearable and/or their activities at home are interfered with too much by noise, one option for residents to consider is to move away from the area. Residents were asked to respond whether they would consider moving away because of such disturbances. The results are shown in Figure 4.12.

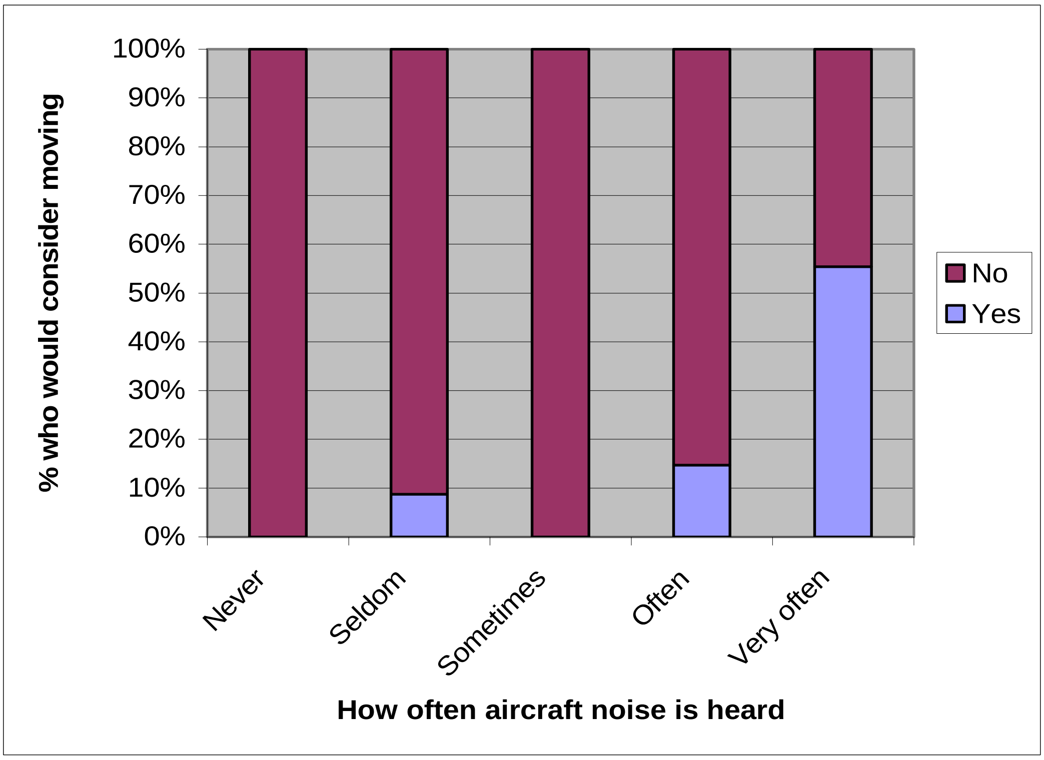


Figure 4.12: Frequency of hearing aircraft noise and desire to move away

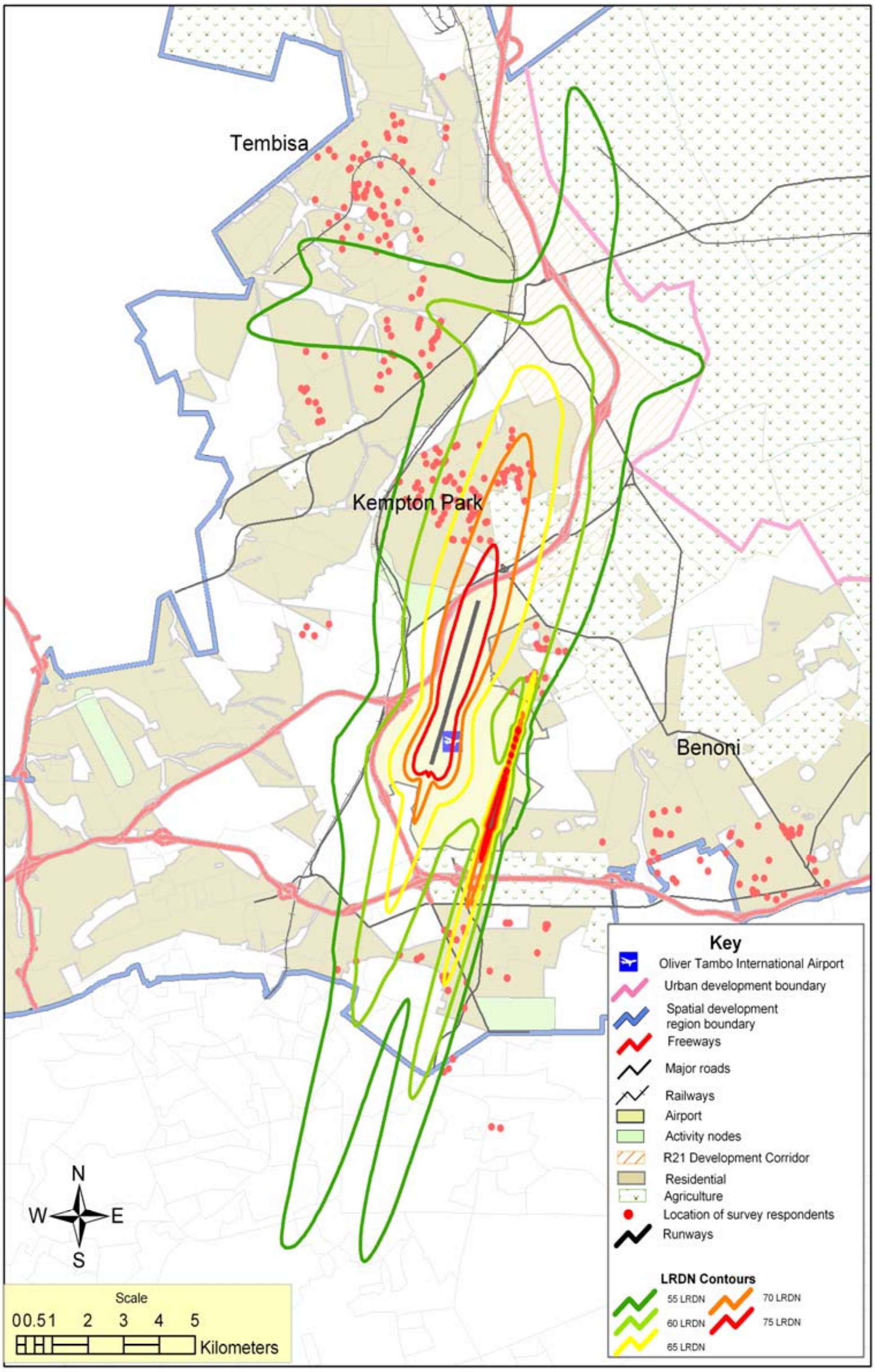
As expected, the residents who responded that they never heard aircraft noise would not move while those residents who heard aircraft noise very often (55.4%) indicated that they would consider moving away (Figure 4.12). This could have implications for property values. If residents who are owners choose to move away, and assuming that these residents would have to sell their properties in order to raise capital to purchase a new property away from the noise, then more houses would come onto the market. An increase in housing supply may result in a reduction of house prices in the area. This was demonstrated by the FAA in a study conducted to assess the reduction in property values of houses near airports (Federal Aviation Administration 1994). The study concluded that aircraft noise reduced property values, and also pointed out that the noise impact on prices of houses in higher-value neighbourhoods is greater than that of houses in lower-value neighbourhoods. In another study McMillen (2004) found that home values within a 65dB noise contour band around Chicago's O'Hare airport were valued about 9% lower than similar homes outside this contour. The results of these two studies would indicate that property values of houses around ORTIA would probably indicate a similar trend.

4.8 INTERPRETING SURVEY RESULTS BY AVERAGE ENERGY L_{Rdn} NOISE ZONES

In this section, the survey results are interpreted according to L_{Rdn} noise contours. The calculation method used to produce the L_{Rdn} noise contour (Figure 4.13) was done as prescribed in the SANS 10117 document. L_{Rdn} contours are usually calculated for a timespan which may be as long as one year. In this study a period of one week was used because the survey investigated respondents' annoyance and irritation over a short period during which they would still have an accurate recall of the noise from aircraft. The survey therefore had a time-critical element to it, as the responses to the noise had to be linked to the flights at that time. The resulting noise contours must therefore be regarded as surrogates of L_{Rdn} noise contours which average noise over a longer period, for example one year.

4.8.1 Interpreting the township response by L_{Rdn} noise contour zones

The response of the township group will be dealt with first, followed by the suburb group. This section considers the degree of reported annoyance to aircraft noise as it varies according to L_{Rdn} zone. Borrowing a concept from GIS, this section may be seen as an attempt to 'ground-truth' the survey results at a local level (Brown 1999) by checking them against international experience. With the exception of two respondents in the township group, all of the Tembisa residents live outside the 55L_{Rdn} contour (Figure 4.13). Of the township respondents living outside the 55L_{Rdn} zone, 42.2% reported being highly annoyed while only 4.7% reported not being annoyed (Figure 4.14). The results of the 55-60 L_{Rdn} are meaningless as there were only 2 respondents (Figure 4.14).



Source: Compiled by author

Figure 4.13: L_{Rdn} contour for the week of the survey

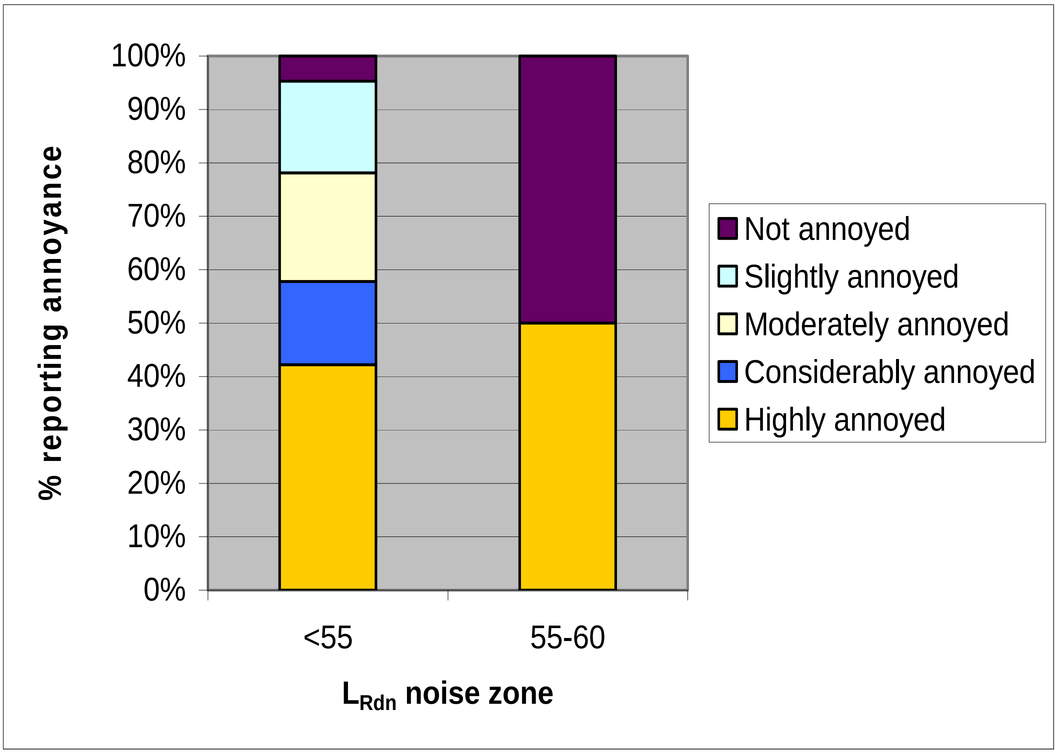


Figure 4.14: Level of annoyance experienced by township residents according to L_{Rdn} noise zones.

4.8.2 Interpreting the suburb response by L_{Rdn} noise contour zones

The suburb residents' responses show a link between increasing annoyance, and L_{Rdn} noise zones zone (Figure 4.15). The 'less than 55L_{Rdn} noise zone' has the lowest percentage (9.8%) of residents reporting being highly annoyed and the highest percentage (65.6%) reporting being not annoyed. The '70-75L_{Rdn} noise zone' has the highest percentage (77.8%) of residents reporting being highly annoyed while there were no residents (0%) reporting being not annoyed. It is interesting to note that the 'highly annoyed' response does not increase consistently in the 66-70L_{Rdn} noise zone. This may be because of the relatively low response in this zone (25 respondents). If the 'considerably annoyed' and 'highly annoyed' responses are read together, then the increase in annoyance is consistent with an increase in noise zone.

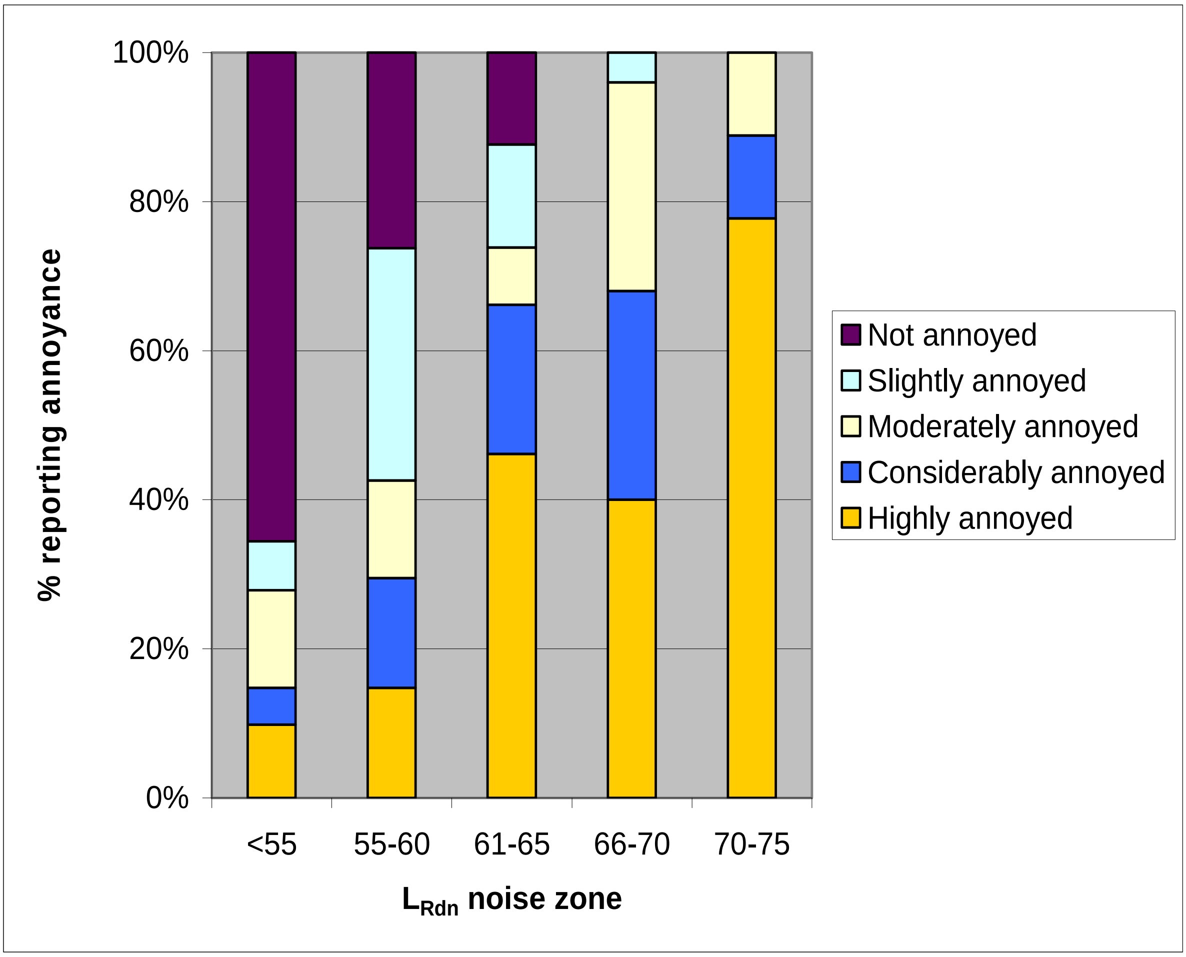


Figure 4.15: Level of annoyance experienced by suburb residents according to L_{Rdn} noise zones

When comparing the results of the township and suburb 'less than 55 L_{Rdn}' noise zone responses, the township respondents reporting being 'highly annoyed' equate to 42.2% while the suburb result is just 9.8%. Only 4.7% of township residents reported no annoyance compared with 65.6% of the suburb residents. In general, the township respondents appear to be more disturbed by noise than suburb residents.

4.9 SUMMARY OF AVERAGE ENERGY RESULTS

Aircraft noise is a problem for neighbourhoods around the airport. The data presented in Figure 4.3 confirms this by clearly indicating that within the experiment group, 33% of respondents who live under or near a flight path are highly annoyed by aircraft noise when compared with the control group where 3% of respondents who live a similar distance from the airport but not near a flight path are highly annoyed. When the experiment group is further separated into the suburb and township groups, a difference in people reporting being highly annoyed emerges. Of the township group 42% were highly annoyed whilst 30% of the suburb group reported being highly annoyed. This is an important finding since the township group are located further from the airport where noise levels are lower (Figure 4.13) and their response was expected to be less annoyed.

In analysing the interference with normal household activities (Figure 4.9) including sleep, television viewing, telephone conversations and work (with the exception of the suburb group reporting on work interference), all of these activities were reported as being interfered with very often by over 22% of respondents. The township group once again reported greater interference with each of these activities than the suburb group.

Average energy noise levels (L_{Rdn})are prescribed by South African national standards for use in land use planning around airports with the aim of separating residential areas from areas exposed to aircraft noise. Quite clearly, from Figure 4.13 this has not been achieved. Residential areas are located in aircraft noise zones up to 20 dB higher than they should be and the consequence is that citizens living in the vicinity of the airport flight paths have a problem with noise. It is also clear that as the average noise levels increase within the noise zones, there is a general trend in increasing annoyance (Figure 4.15) where in the 70-75 L_{Rdn} zone almost 80% of respondents are highly annoyed.

The foregoing discussion confirms the specific objective (3rd bullet) namely:

- Establish that communities experience annoyance from aircraft noise even when they are located outside 55 L_{Rdn} aircraft noise contours.

These results are illuminating, and in line with groundtruthing, the next chapter considers the results in terms of supplemental aircraft noise information.

CHAPTER 5: SURVEY RESULTS: INTERPRETED ACCORDING TO SUPPLEMENTAL NOISE INFORMATION

Many studies have been done to assess the annoyance and disturbance caused by aircraft noise when the noise is averaged over a 24-hour period. The most seminal work is that of Schultz (1978) in which he synthesised the results of 11 'clustering surveys', conducted to assess the magnitude of transportation noise problems. Schultz found that a relationship could be established between increasing noise levels and annoyance.

The survey respondents in this study generally reported more annoyance than found by Schultz. However, the surveys reviewed by Schultz all covered 24-hour periods, whereas the present survey required respondents to answer questions about noise experienced over a 12-hour period between 18:00 and 06:00.

At a first glance, when compared with Schultz's findings, the survey responses in this study seem to be more acute. In other words, the average response in the ORTIA study seems to reflect that residents living around the airport are more sensitive to noise, however, the survey did cover a time period when respondents are more likely to be disturbed.

The problem of sleep disturbance by aircraft in Holland led to an investigation by Wijnen & Visser (2003) designed to optimise flight trajectories to minimise sleep disturbance. The goal of their research was to integrate the Integrated Noise Model and a GIS to develop flight paths which would deviate laterally from the reference flight track if this lessened the noise impact by reducing the population numbers affected by aircraft noise. A further noise mitigation step would be to incorporate supplemental noise information into that which town planners and residents have available and to assist them with making decisions about locating near airports.

In this chapter the survey results are interpreted according to the required supplemental aircraft noise descriptors.

More recently, Hume et.al (2003) have shown that when analysed over a 24 hour period, night flights caused an average of 5 times more complaints than the rest of the day, with the time of greatest propensity to complain being 01h00 and 02h00. This will be shown in the following graphs and the reason why explained.

5.1 EVALUATION OF SURVEY RESPONSES ACCORDING TO THE 12-HOUR L_{Aeq} EVENING & NIGHT NOISE CONTOUR

The L_{Rdn} noise contours discussed in the previous chapter modelled the average noise exposure over a 24 hour period. This is unrealistic because residents are not at home for a large proportion of the 24 hour period. For example work commitments and education require many people to leave home in the morning and return much later in the day. It seems more meaningful to match residents' feelings about aircraft noise to those times when they are likely to be at home. This means that the L_{Rdn} contours cannot be used, since they are 24-hour average contours. The purpose of this section is to analyse what people's responses are based on the 12-hour L_{Aeq} noise contour zone which they live in.

It is expected that most residents are at home in the 12-hour evening and night period from 18:00 to 06:00. Supplemental noise information was therefore calculated, and used to provide noise information about the times when people are at home. The first example of supplemental noise information to be analysed is the average aircraft noise level to which residents are exposed when they are at home. For the purpose of this study, it was assumed that residents are at home between 18:00 and 06:00.

The aircraft movement records for the study period were accessed, and all aircraft operations at the airport between 18:00 and 06:00 extracted. These movements were then pre-processed as described previously, and then captured into the INM. A 12-hour L_{Aeq} noise simulation run was conducted and a series of noise contours at 5dB intervals from $55L_{Aeq}$ to $65L_{Aeq}$ produced. A $70L_{Aeq}$ noise contour was also produced, but this contour was almost entirely on the airport property and therefore discarded as it did not impact on residential areas. The noise contours were exported as shape files, then imported into the GIS. The spatial extent of the 12 hour L_{Aeq} noise contour was such that it did not extend as far as Tembisa. The analysis in this section will therefore focus on the suburb respondents.

Four L_{Aeq} noise zones were produced: <55, 55-60, 61-65 and >65. The residents' responses according to the 12-hour night L_{Aeq} contour were statistically extracted according to the noise zone they were located in. It is emphasised that the survey responses remain the same. It is just the noise zone that the residents live in, calculated according to a 12-hour evening and night average that changes. In Figure 5.1 the 12 hour night L_{Aeq} noise contours are plotted. During the 12-hour evening and night period from 18:00 to 06:00, there were an average of 124 aircraft movements as opposed to an average of 497 daily movements in the 24 hour period. Although the evening and night noise was averaged over a 12-hour period, the reduced number of aircraft movements (373 fewer movements) and the fact that no weighting was applied to the 12-hour evening and night L_{Aeq} contour calculation, the spatial extent of the evening and night noise contour (Figure 5.1) is smaller than the 24 hour L_{Rdn} contour (Figure 4.13).

The degree of annoyance increases directly with increasing noise level zone, except in the 61-65 L_{Aeq} noise zone where there is a decrease in the highly annoyed responses (Figure 5.2). This could be because there were only 21 respondents in this zone. If the two highest levels of annoyance are combined, the direct relationship is more consistent. Two thirds of the respondents in both the 55-60L_{Aeq} noise zone and in the 61-65L_{Aeq} noise zone were considerably or highly annoyed.

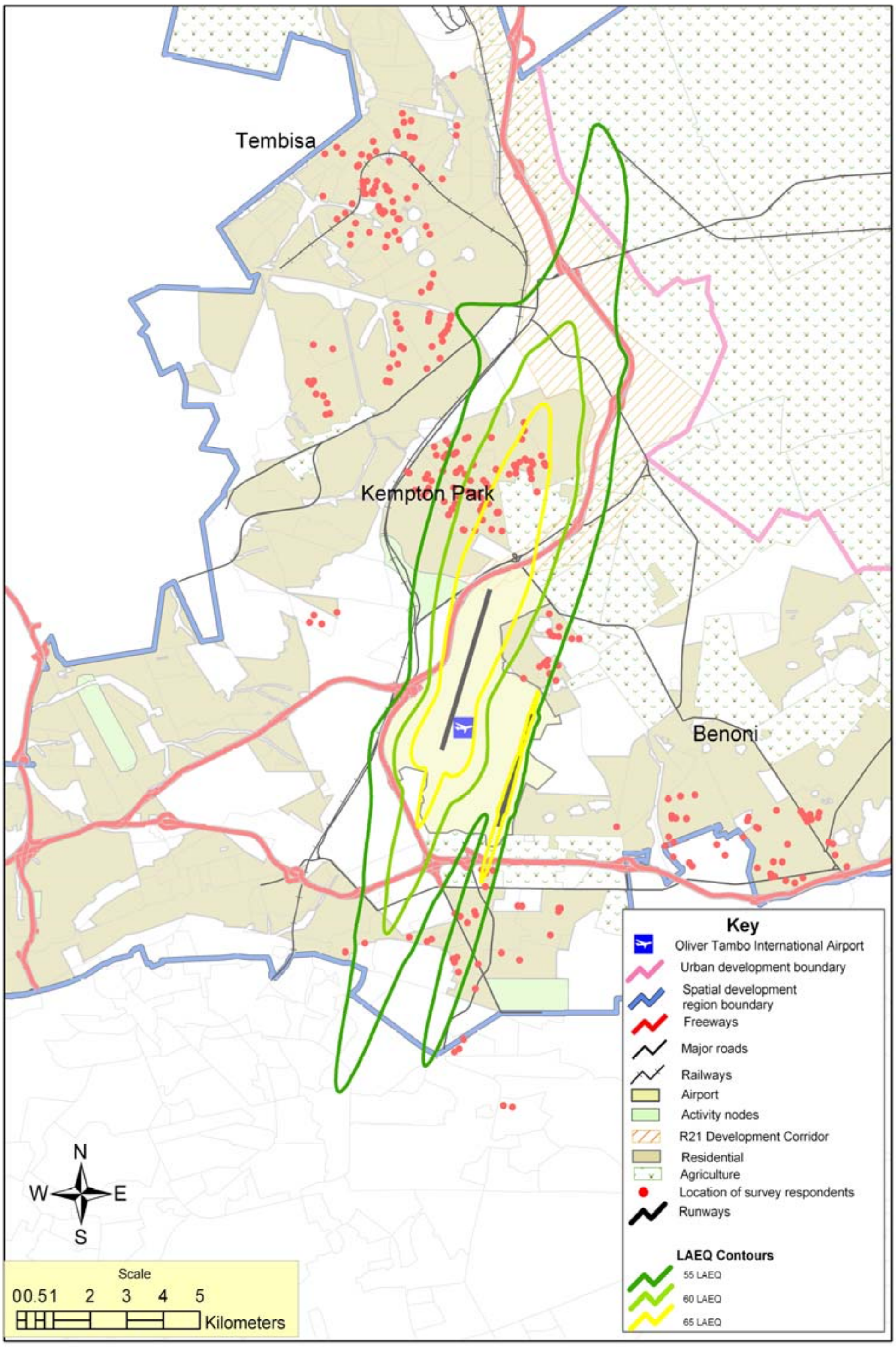


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Figure 5.1: 12-hour night L_{Aeq} noise contours at ORTIA

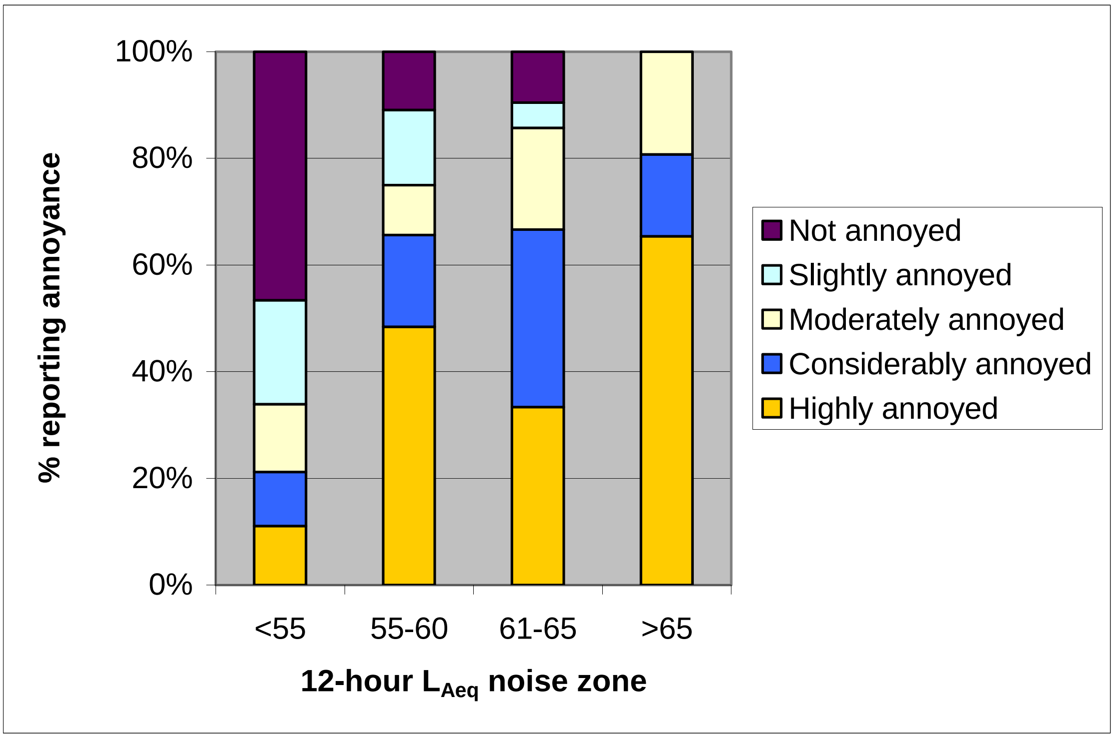
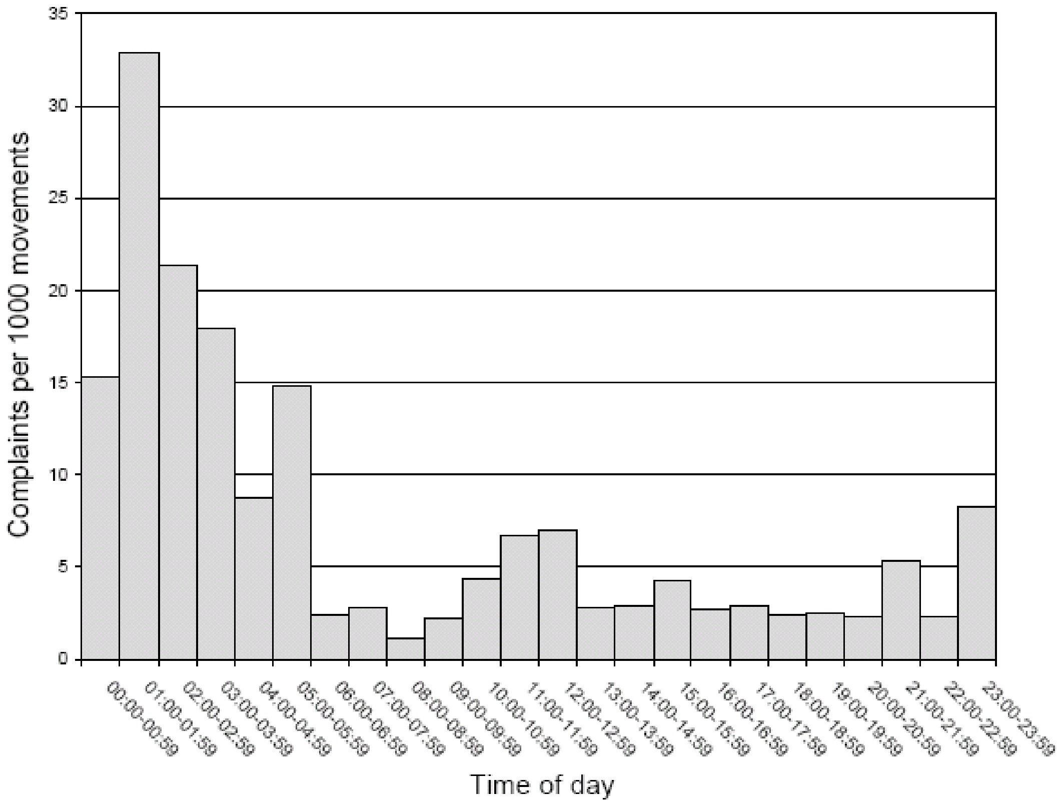


Figure 5.2: Level of reported annoyance experienced by suburb residents according to 12-hour L_{Aeq} noise zones

If the moderately annoyed responses are added to the considerably and highly annoyed responses, the annoyance response correlates highly with the increasing noise zone level. In the >65L_{Aeq} noise zone, the combined moderately to highly annoyed responses indicate that all the respondents in this zone were annoyed by aircraft noise at night. This result can be viewed against the findings of Hume et al. (2003) in which noise complaints for each hour of the day were matched with aircraft movements (Figure 5.3). It is evident that the most complaints per 1000 movements were received between 23:00 and 05:59 which are normal sleeping hours.



Source: Hume et al. 2003:158

Figure 5.3: Specific noise complaints (per 1000 movements) for each hour of the day at Manchester Airport

Because complaints are actions which arise out of annoyance, this casts further light on the results in Figure 5.2. Annoyance finds expression in complaints particularly at night in the early stages of sleep when there is a predominance of slow-wave sleep with the highest sleep arousal threshold. Residents whose sleep is disturbed experience greater levels of distress which contributes to increased annoyance leading to a greater level of complaints (Hume et al 2003).

5.1.1 Comparison between suburb 24 hour L_{Rdn} and 12 hour L_{Aeq}

In Figure 5.4 the annoyance level responses are displayed according to the L_{Rdn} and L_{Aeq} noise contours. The combined considerably and highly annoyed responses reveal a trend for annoyance to increasing with noise level. Also evident is that, with the exception of the 61-65L_{Aeq} noise zone, the annoyance responses for the 12-hour L_{Aeq} noise contours are more intense than the 24-hour L_{Rdn} noise zones.

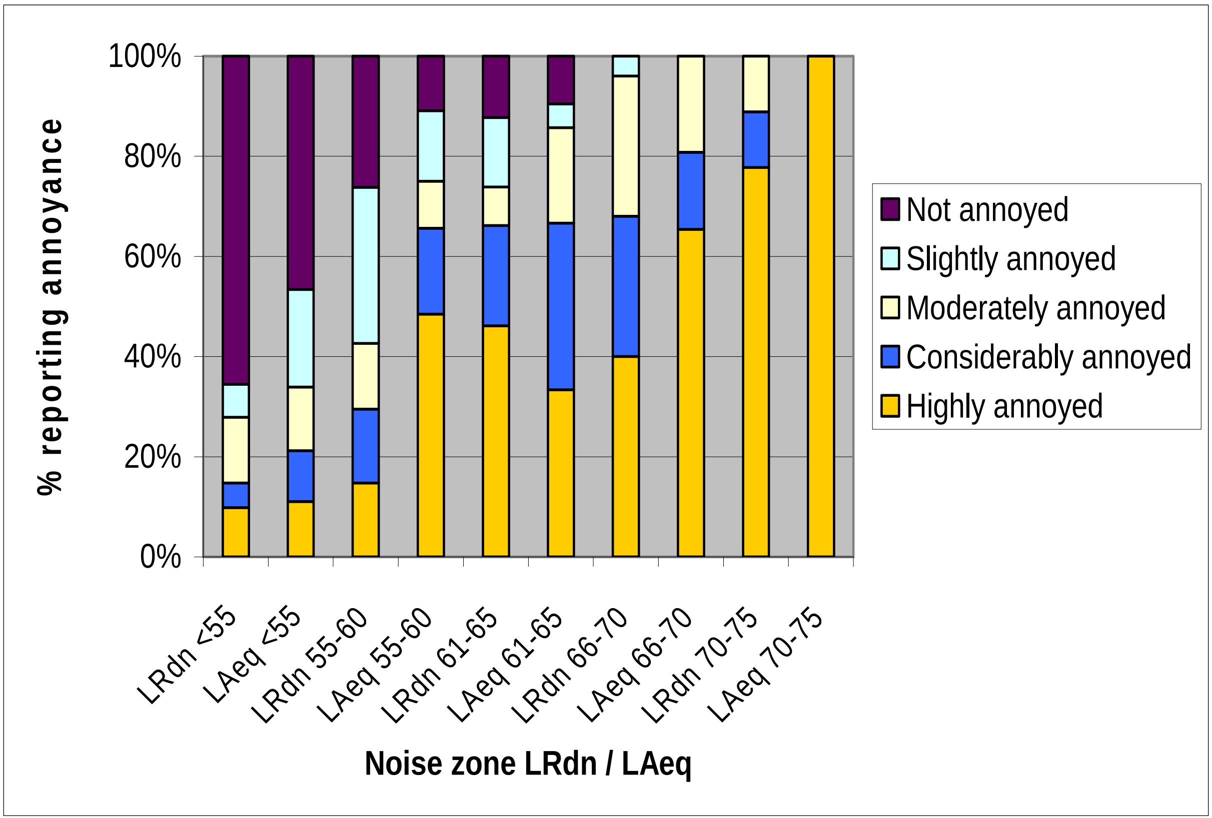


Figure 5.4: Level of annoyance experienced by suburb residents according to 12-hour LAeq and 24 hour LRdn noise zones

5.1.2 Noise interference with household activities: Sleep, Phone, TV, Work/study

In this section aircraft noise interference with four household activities; namely sleep, telephone conversations, television viewing and work or study is discussed.

5.1.2.1 Sleep disturbance

Sleep disturbance is an important consequence of night-time aircraft noise (Figure 5.5). The percentage of respondents reporting their sleep never being disturbed by aircraft noise is highest in the <55L_{Aeq} noise zone, whereas at the level of >65L_{Aeq}, no respondents reported never being disturbed. This confirms the expectation that as noise increases, so residents will experience more sleep disturbance. The proportion of residents reporting their sleep being disturbed very often, increases from the

<55L_{Aeq} noise zone (12%) to the >65L_{Aeq} noise zone (50%) with the exception of the 61-65L_{Aeq} noise zone (25%). Approximately 35% of the respondents in the 55-60L_{Aeq} noise zone report having their sleep disturbed very often. This is a significant finding. If this supplemental aircraft noise information were to be made available to residents, those individuals who believe that their sleep may be disturbed may elect not to live in the noise zones where sleep disturbance has been reported.

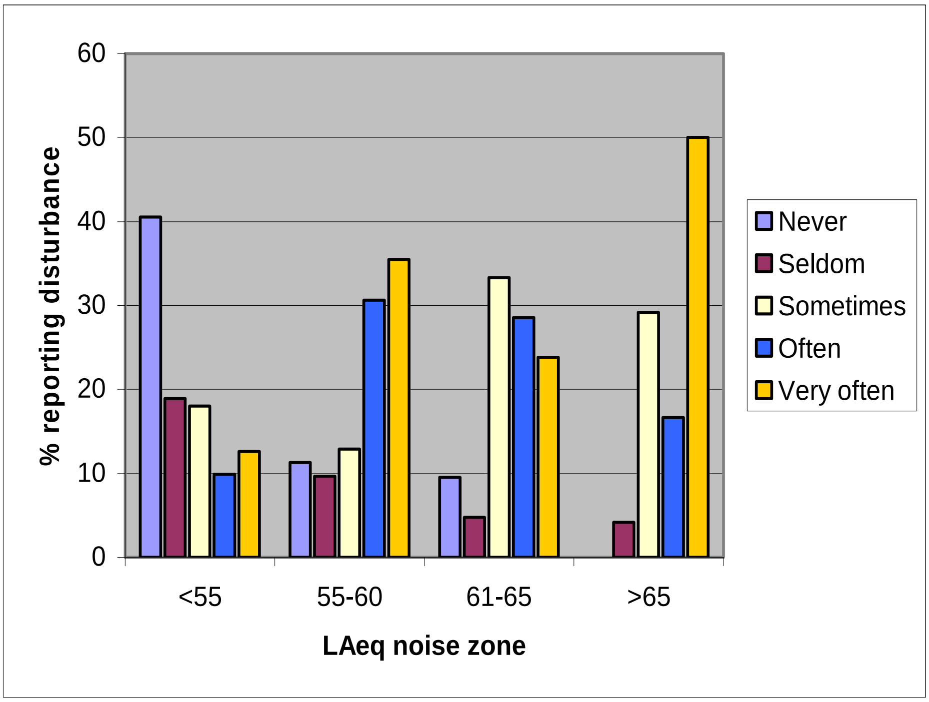


Figure 5.5: Frequency of sleep disturbance in the suburb group per 12-hour night L_{Aeq} noise zone

5.1.2.2 Telephone conversation disturbance

Frequency of interference with telephone conversations is illustrated in Figure 5.6. More than 60% of respondents in the >65L_{Aeq} noise zone report being disturbed very often. On the other hand about 37% of respondents in the <55L_{Aeq} noise zone report that their conversations are never disturbed. However, this also means that about 63% of respondents still experience some disturbance of telephone conversations in the latter zone where the noise level is the lowest.

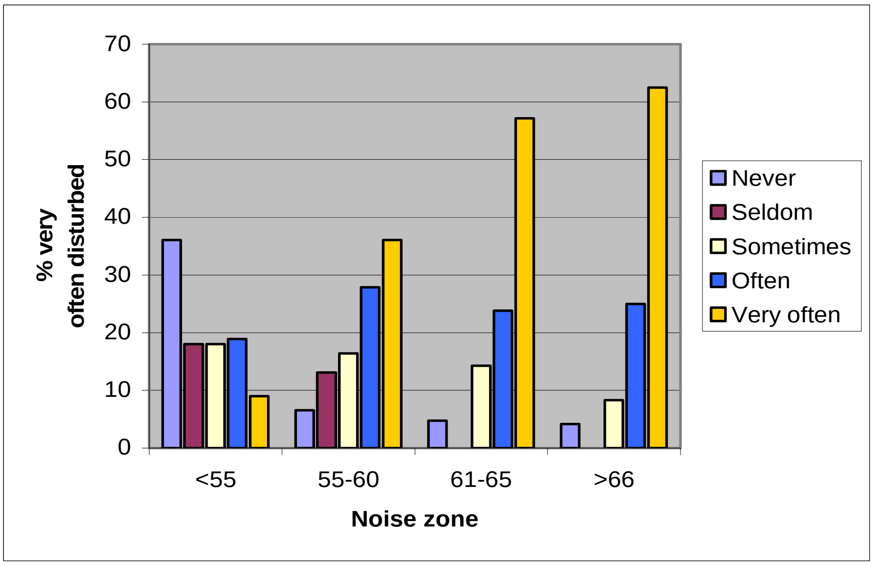


Figure 5.6: Frequency of interference with telephone conversations among the suburb group per 12-hour night L_{Aeq} noise zone

5.1.2.3 Television viewing disturbance

Approximately 30% of residents in the <55L_{Aeq} noise zone reported that television viewing is never disturbed by aircraft noise (Figure 5.7) while 70% did report some disturbance. In each of the noisier zones more than half of the respondents reported their television viewing being disturbed very often. No respondents in the 61-65L_{Aeq} and >65L_{Aeq} noise zones reported that they are never, or even seldom disturbed.

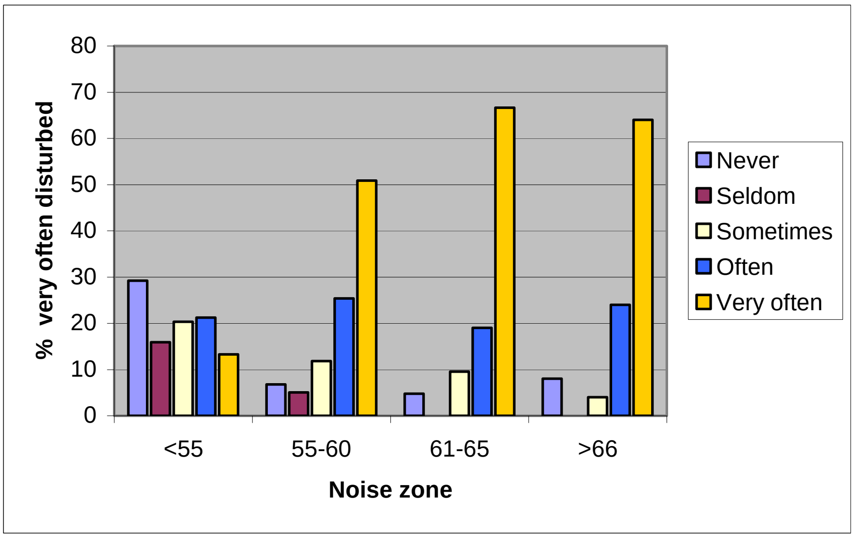


Figure 5.7: Frequency of interference with television viewing among the suburb group per 12-hour night L_{Aeq} noise zone

5.1.2.4 Work or study disturbance

The work or study variable shows a clear relationship between increasing noise level and reported disturbance (Figure 5.8). As the noise zone increases, the percentage of respondents reporting that they are never disturbed decreases from 45% in the <55 L_{Aeq} noise zone, to less than 10% in the >66 L_{Aeq} noise zone.

There is also a clear increase in the percentage of respondents reporting being disturbed very often. Approximately 5% of respondents are disturbed very often in the <55 L_{Aeq} noise zone and 50% are disturbed very often in the >66 L_{Aeq} noise zone.

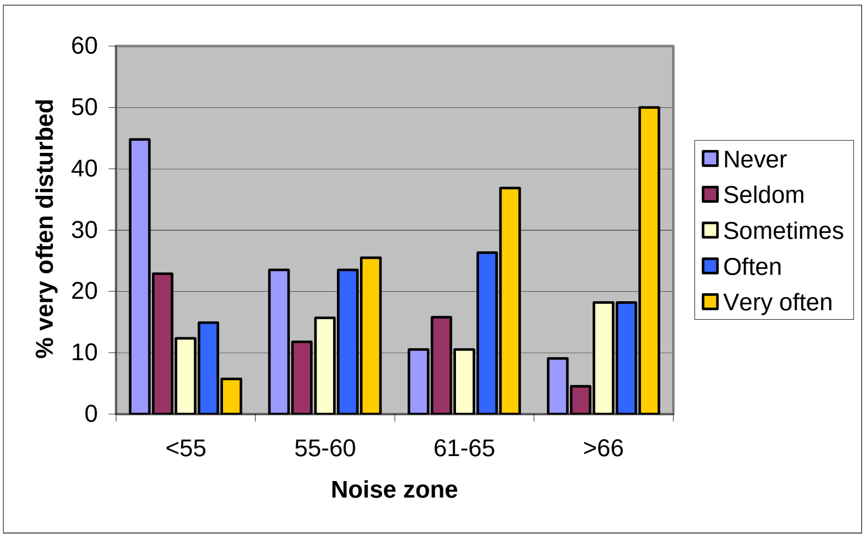


Figure 5.8: Frequency of interference with work or study among the suburb group per 12-hour night L_{Aeq} noise zone

It was stated in the research objectives that it would be established that communities living outside the 55 L_{Rdn} aircraft noise contour line experience annoyance from aircraft noise. From the preceding graphs it is apparent that up to 20% of respondents living outside of this noise zone are often or very often disturbed thus confirming this particular stated research objective.

5.1.3 Comparison of responses by L_{Aeq} noise zones and by household activities interfered with

Following Riley's (1990) example of progressive focusing where data are examined in different ways, the data were redrawn to illustrate and compare the activity disturbance between the L_{Aeq} noise zones with one another (Figure 5.9) and the L_{Aeq} noise zones with the activities (Figure 5.10).

5.1.3.1 Comparison by noise zone of respondents reporting being disturbed very often: sleep, telephone conversations, television viewing and work or study

In Figure 5.9, each of the four activities investigated are grouped by noise zone according to the 'very often' response. Below 55L_{Aeq}, reported disturbance across the four activities varies between five and 13 percent. The noise level is not very loud here and this result is expected. As the noise zone level increases, there is an increase in the frequency of reported disturbance of the activities. Television viewing disturbance shows the greatest increase as the noise levels increase across the noise zones. Reported television viewing disturbance is also the highest in each noise zone when compared with sleep, telephone conversations and work or study. With the exception of the <55 L_{Aeq} noise zone, telephone conversations are reported to have the second highest level of disturbance. Sleep disturbance does not follow a consistent pattern of increase with increasing noise zone. There is a decrease in reported disturbance in the 61-65L_{Aeq} noise zone and an increase in the >65L_{Aeq} noise zone again.

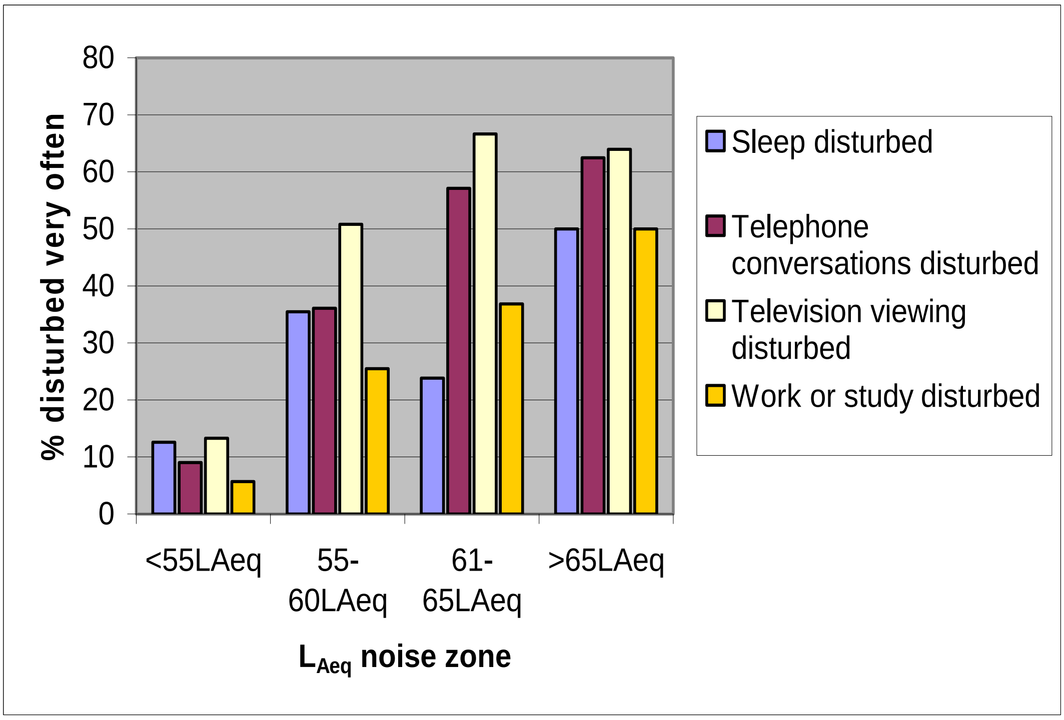


Figure 5.9: Disturbance of household activities by aircraft noise according to L_{Aeq} noise zone

5.1.3.2 Comparison by activity disturbed of respondents reporting being disturbed very often: sleep, telephone conversations, television viewing and work or study

In Figure 5.10, responses are grouped by activity to permit a comparison across noise zones. The activities generally show an increase in disturbance across noise zones with two exceptions. In the sleep disturbance grouping the 61-65L_{Aeq} noise zone breaks the pattern with a decrease, and in the television viewing grouping the >65L_{Aeq} noise zone disturbance is slightly lower than the 61-65L_{Aeq} noise zone. Television viewing is clearly reported as being the most disturbed.

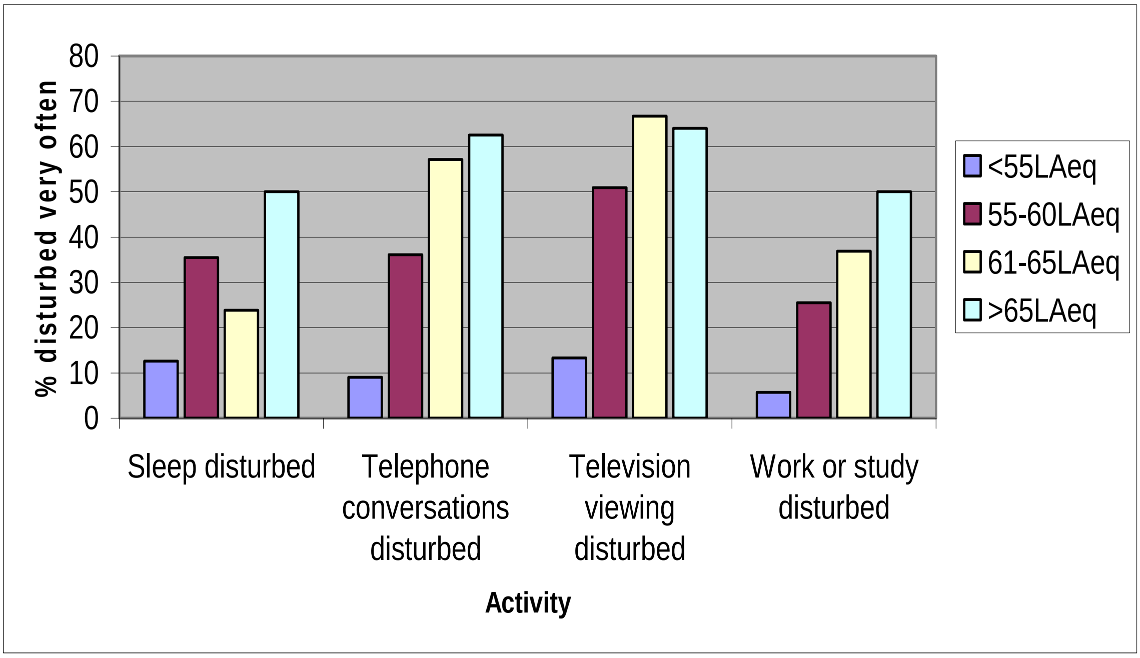


Figure 5.10: Noise zone disturbance according to household activities

5.2 EVALUATION OF SURVEY RESPONSES ACCORDING TO THE THREE 'NUMBER OF EVENTS' CONTOURS (N60, N70, N80)

'Number of events' is a concept developed in TNIP whereby the number of aircraft noise events above specified threshold noise levels are portrayed on land-use maps. Three 12-hour 'number of events' contours were produced; namely the number of events above 60, 70 and 80dBA. The spatial extent of these contours is displayed in Figures 5.11 to 5.13[6].

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[6] The mapped area of the N60 contour in Figure 5.11 and the N70 contour in Figure 5.12 only includes the contour where it intersects the study area because both the N60 and the N70 contours extend beyond the study area boundaries. A portion of each of the N60 and N70 contours were therefore excluded. To include the whole contour would have meant altering the maps to a smaller scale which would result in the points which represent the survey locations merging into one another and obscuring detail. For consistency, it was necessary to keep the N60, N70 and N80 contours the same scale so the non-essential portions of the contours were trimmed and the scale detail of the study area retained. For the full spatial extent of the N60 and N70 contours, please consult Figures C1 and C2 in Appendix C.

5.2.1 General discussion of the shape of the number of events contours.

Several factors affect the size and shape of an individual aircraft's noise signature. Generally aircraft make more noise on departure than they do when landing because the engines are operated at, or close to, full power. If there are no air traffic control restrictions, a departing aircraft on a short-haul flight can gain altitude quickly, and so its noise footprint will decrease quickly. However, a heavily loaded widebody jet departing on an intercontinental flight will climb slowly so that its noise footprint for departure is greater. The noise contour of a departing aircraft is typically quite long and wide while an arriving jet's noise contour is narrow and short by comparison.

In the case of landing aircraft, pilots are required to fly what is known as a stabilised approach. This means the aircraft is lined up with the runway, and follows the instrument landing system between 15 and 20 km from touchdown and descends at a controlled angle of three degrees. The engines on an arriving aircraft are throttled back, but pilots often have to make minor adjustments to the power levels to maintain the three degree steady descent to the runway. The resulting noise contour of a landing aircraft is therefore quite long, but narrow compared to a departing aircraft. These differences in power settings are evident in the size and shape of the noise contours shown in Figures 5.11 – 5.13.

In the week of the study during which aircraft operational data and the survey responses were elicited, the air traffic flow was predominantly from the south to the north. This means that whichever airport the aircraft was arriving from, or departing to, arriving aircraft would have approached the airport from the south, and departed to the north. Of the arriving aircraft, most landed on the eastern runway, known as runway 03 Right. In the case of departing aircraft, most took off from the western runway, known as Runway 03 Left [7].

With this understanding, the general size and shape of the 'Number of Events' contours can be explained.

[7] Airport runways are named after the magnetic compass heading they point towards, rounded off to the nearest 10, then the 0 at the end of the heading is removed. For example a runway pointing to a direction of 150 degrees would be called Runway 15 and in the opposite direction, Runway 33.

5.2.1.1 Number of events above 60L_{Amax} contour

The spatial extent of the N60 L_{Amax} contour illustrated in Figure 5.11 is larger than that of the N70L_{Amax} and N80L_{Amax} contours (Figures 5.12 and 5.13). As departing aircraft climb away from the airport, the noise energy transmitted to the ground decreases. This means that fewer noise events above 60L_{Amax} are heard as distance from the airport increases.

In Figure 5.11, the N60L_{Amax} contour to the south of the airport is narrower compared with the contour to the north. The relative narrowness is due to the aircraft following the stabilised approach to the runway. Regarding the approach to runway 03 Right, the eastern portion of the contour in Boksburg has a steep gradient where the number of events decreases sharply from 50 events to less than10 events in a distance of about 500m. The western edge of the contour has a gentler gradient. This is due to the relatively fewer numbers of arrivals onto runway 03 Left. To the north of the airport, the noise contour is wider and the noise impact greater. This is due to the high power setting used by departing aircraft, and the fact that the aircraft are turning onto a heading commensurate with their intended destination.

5.2.1.2 Number of events above 70L_{Amax} contour

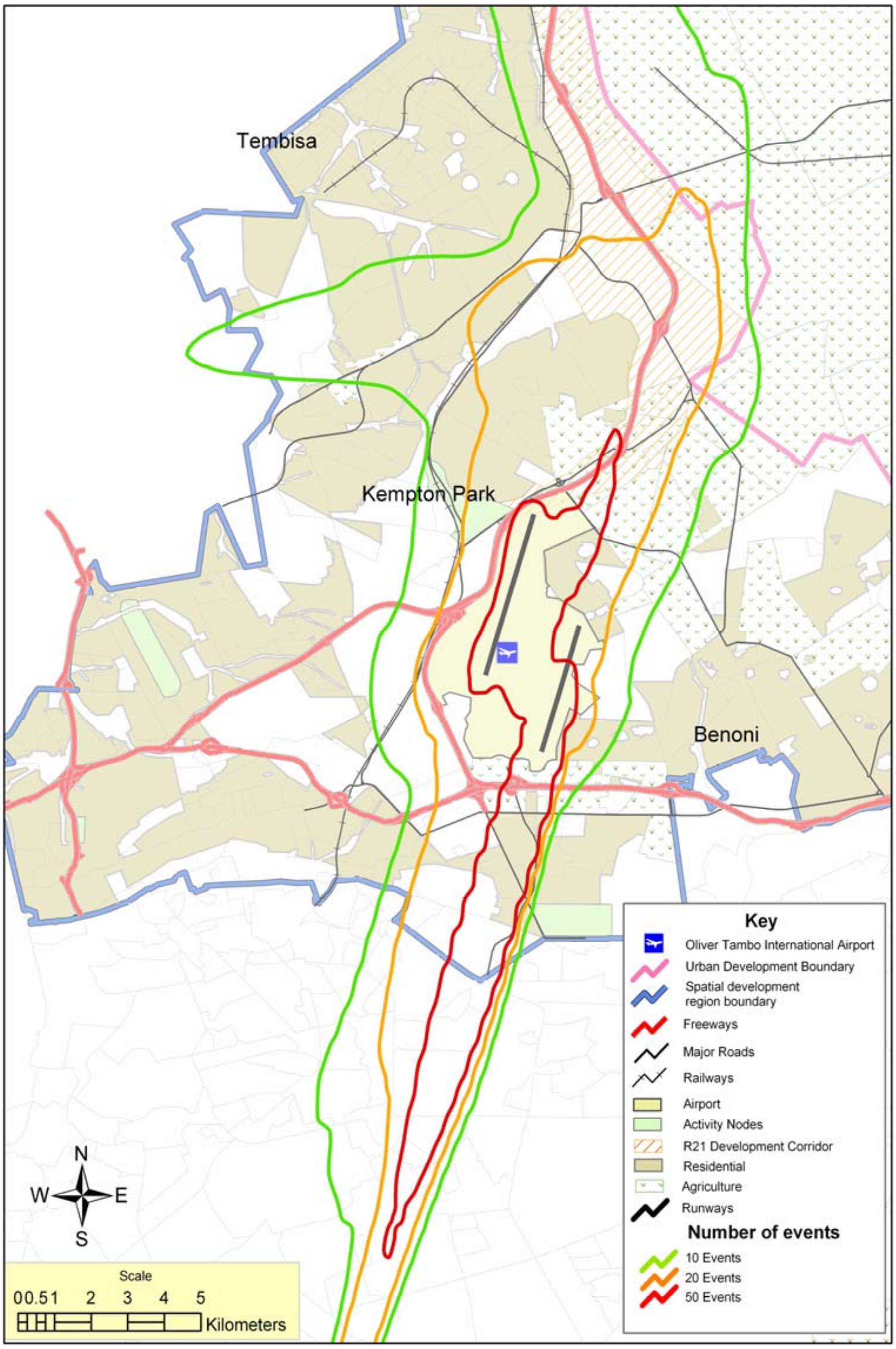
The spatial extent of the N70L_{Amax} contour (in Figure 5.12) differs quite significantly from the N60L_{Amax} contour. Firstly, the 10 events noise lobe to the west (between Tembisa and Kempton Park) has disappeared. This means that there are no events exceeding 70L_{Amax} over these areas. The noise lobes to the south and north have also become narrower and shorter. Whilst the spatial extent of the N70L_{Amax} contour is smaller, the intensity of the noise is greater. Residents living in these areas will be exposed to noise within the N60L_{Amax} contour, as well as the N70L_{Amax} contour.

5.2.1.3 Number of events above 80L_{Amax} contour

The N80L_{Amax} contours are the smallest in spatial extent of all the number of events contours. However, the noise intensity is also the highest, with residents being exposed (in addition to noise above 60L_{Amax} and 70L_{Amax}) to noise above 80 L_{Amax} in these areas. The large lobe which extends to the north is caused by widebody jets departing for European destinations. These aircraft carry a heavy fuel load for the flight and climb slowly thereby causing greater noise closer to the ground.

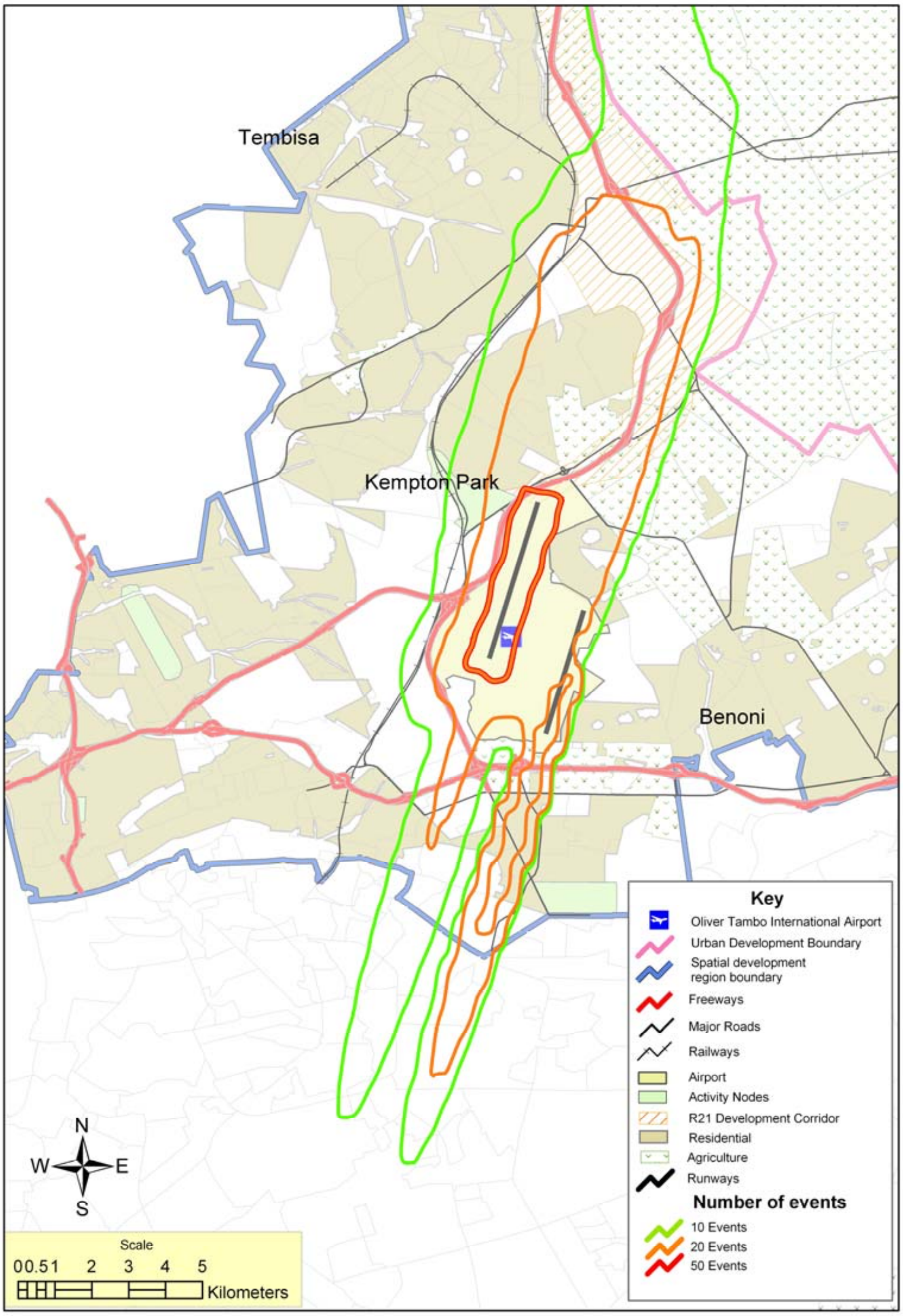
To continue exploring the research objectives and the reported problems with airport noise, the following analysis of Number of Events is presented.

Firstly, reported annoyance according to the number of events will be discussed. Thereafter, sleep, TV, telephone, work/study will be discussed, and then whether residents will consider moving. There is any amount of flexibility in deciding what the number of events should be, and what the levels of the events should be. In the present study, the number of events were classified according to the Commonwealth Department of Transport and Regional Services (2000) i.e. <10 events above, 10-20 events, 21-50 events and > 50 events at specified levels of 60dBA, 70 dBA and 80 dB(A). Any choice of number of events and/or noise level of the events is possible. The number of events is a relatively new concept, and it was decided to follow the divisions selected by the Commonwealth Department of Transport and Regional Services so that future comparisons may be made. It is not improbable that future research will also follow this example, making this research forward compatible for the future.



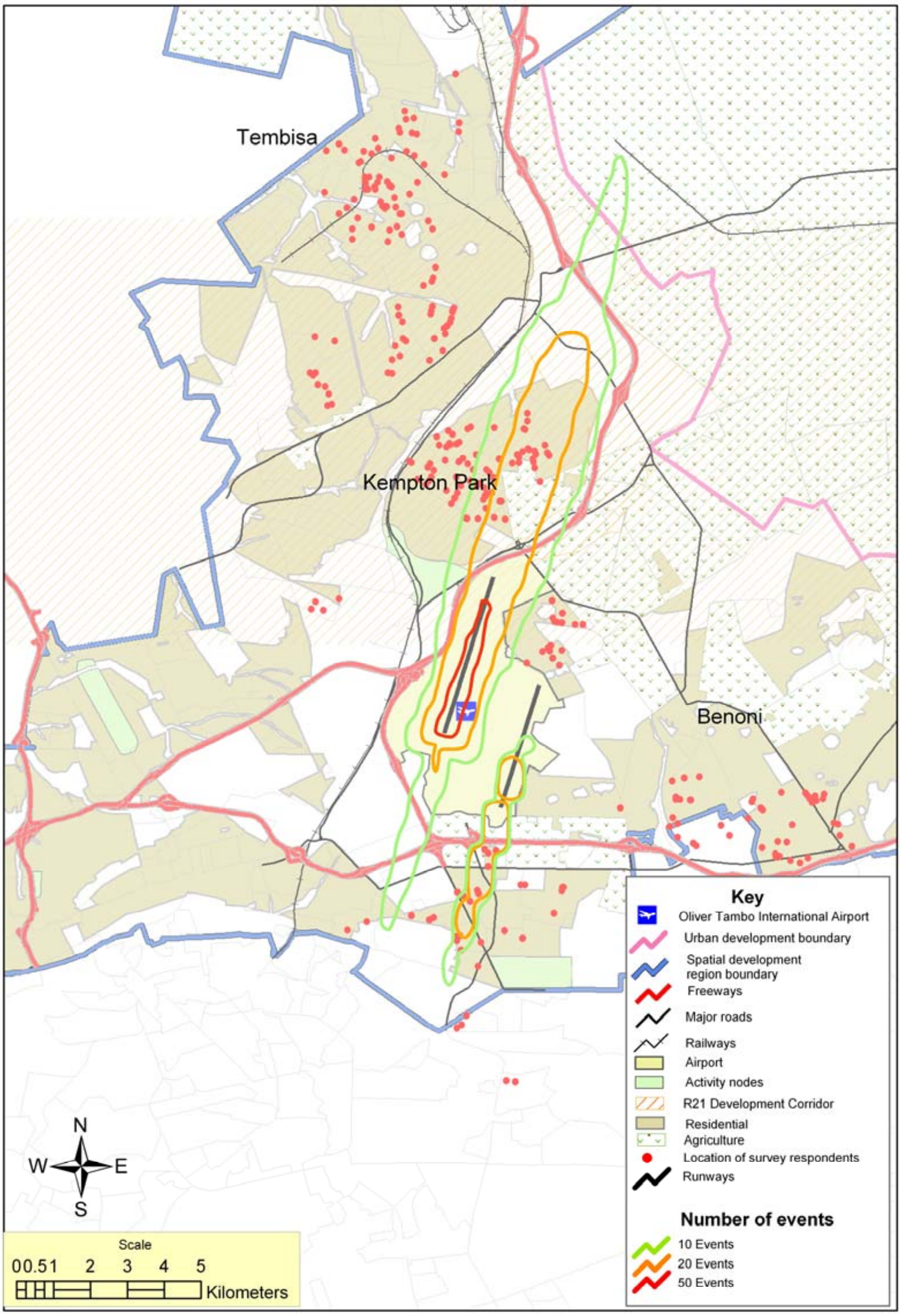
Source: compiled by author

Figure 5.11: 12 hour 18:00-05:59 N60 contour



Source: compiled by author

Figure 5.12: 12 hour 18:00-05:59 N70 contour



Source: compiled by author

Figure 5.13: 12 hour 18:00-05:59 N80 contour

5.2.2 ANNOYANCE ACCORDING TO NUMBER OF EVENTS

A trend exists in Figure 5.14 that as the number of events increases, so does the reported annoyance. Similarly, noise level and annoyance are directly related. The exception is at the >50 events level, where the N80L_{Amax} is slightly less than N70L_{Amax}. There were only nine respondents in this N80L_{Amax} >50 events category. The results suggest that at greater than 50 events, whether noise level is fairly low, at N60L_{Amax} or higher, at N80L_{Amax} reported annoyance levels off between 85 and 94% respondents reporting considerable to high annoyance. Generally, annoyance increases with number of events and the noise level of these events. It is quite clear that the number of events plays a larger role in creating annoyance when the occurrence of <10 events and >50 events are compared. In the case of the occurrence of 10-20 events, the noise level plays an important role. At busy airports, these number of events contours should be used for land use planning rather than noise level contours.

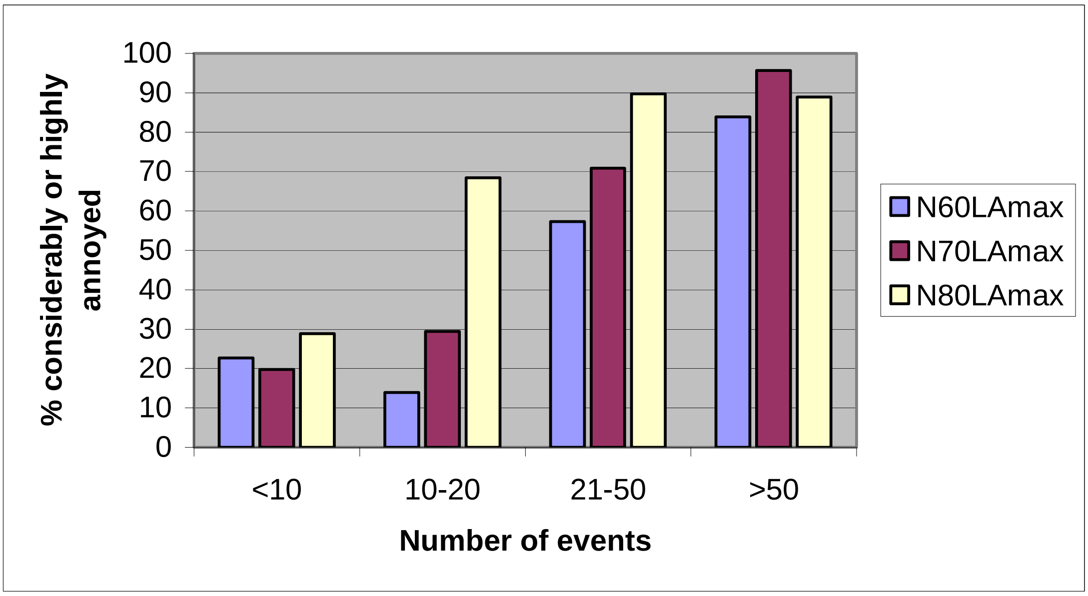


Figure 5.14: 12-hour N60, N70, N80 suburb group reporting being considerably or highly annoyed

5.2.3 SLEEP DISTURBANCE REPORTED ACCORDING TO NUMBER OF EVENTS

Some sleep disturbance is reported at less than ten events and noise levels of $N60L_{Amax}$ and $N70L_{Amax}$ (Figure 5.15). At less than 10 events, a level of $N80L_{Amax}$ disturbs about 30 percent of the respondents. Thereafter, as the number of events increases, there is a fairly consistent increase in disturbance with increasing noise level. At the >50 events level, the $N60L_{Amax}$, $N70L_{Amax}$ and $N80L_{Amax}$ are all over 80% indicating that the number of events is more important to people than the actual level.

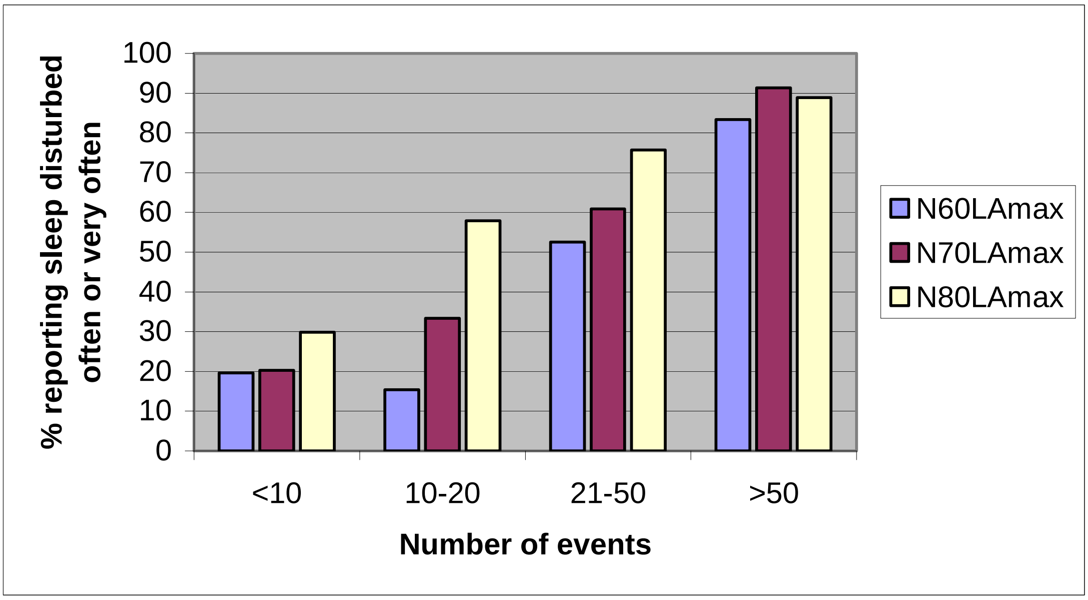


Figure 5.15: 12 hour N60, N70, N80 Sleep reported as being often and very often disturbed

5.2.4 TV VIEWING DISTURBANCE REPORTED ACCORDING TO NUMBER OF EVENTS

A general increase in reporting disturbance of television viewing is evident across the number of events and the noise level of the events in Figure 5.16. An anomaly exists at the number of events above $80L_{Amax}$ in the 10-20 events noise zone where over 90% of respondents reported being disturbed often or very often. It is clear though that people find aircraft noise disturbing to their television viewing since, with the exception of one noise zone (ie. 10 – 20 events), all other responses are over 35% and six are more than 80%.

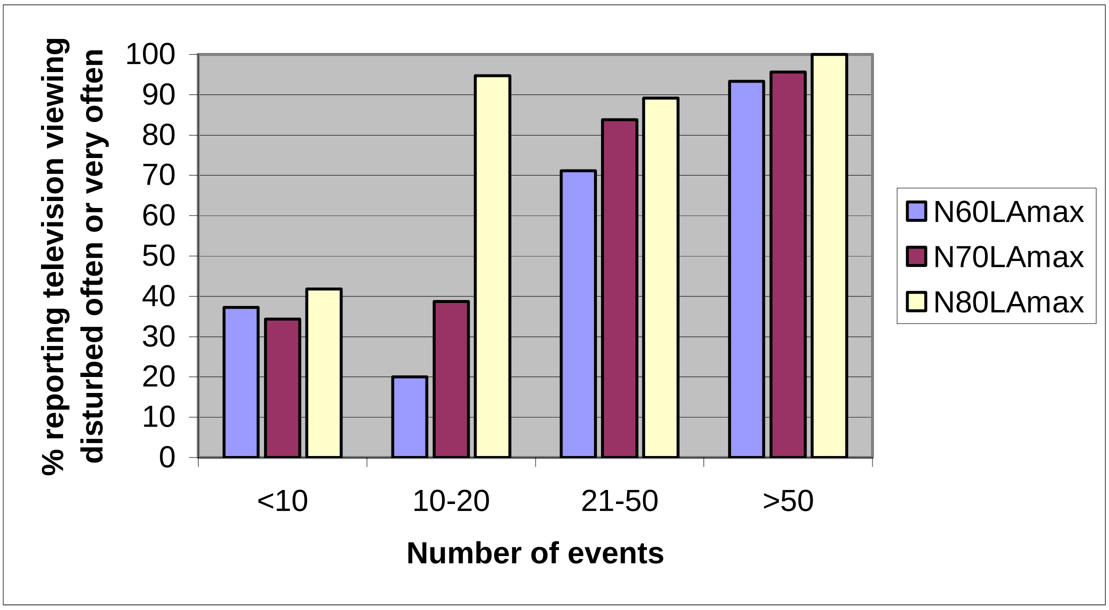


Figure 5.16: 12 hour N60, N70, N80 TV viewing reported as being often and very often disturbed

5.2.5 TELEPHONE CONVERSATION DISTURBANCE REPORTED ACCORDING TO NUMBER OF EVENTS

Figure 5.17 illustrates the disturbance made by aircraft noise to telephone conversations according to number of events. Events over $80L_{Amax}$ show a large increase in the 10-20 events zone and remains fairly constant in the 21-50 and >50 zones. The responses in N60 contour and the N70 contours are not as pronounced as the N80, but it is clear that people in these zones also report disturbance.

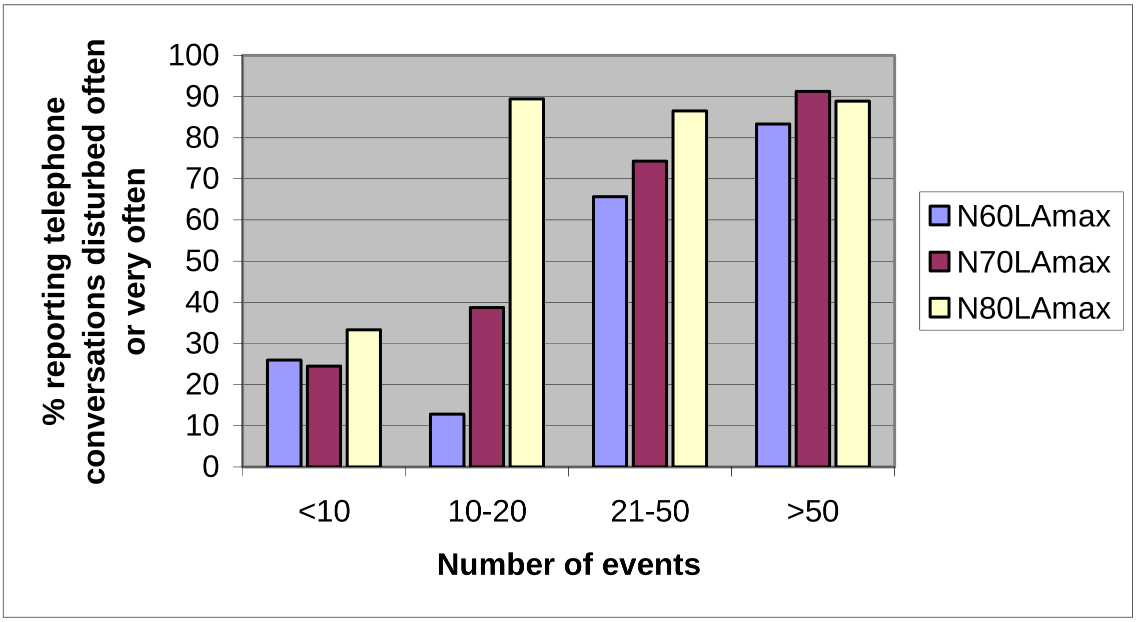


Figure 5.17: 12 hour N60, N70, N80 Telephone conversations reported as being often and very often disturbed

5.2.6 WORK OR STUDY DISTURBANCE REPORTED ACCORDING TO NUMBER OF EVENTS

In Figure 5.18, the pattern of increased interference with increasing number of events and increasing noise level is continued. The N80 response again shows a disproportionately large percentage of people reporting disturbance in the 10 - 20 events category. It remains clear though that an increasing number of events even at the relatively low noise level of N60 is responsible for more disturbance.

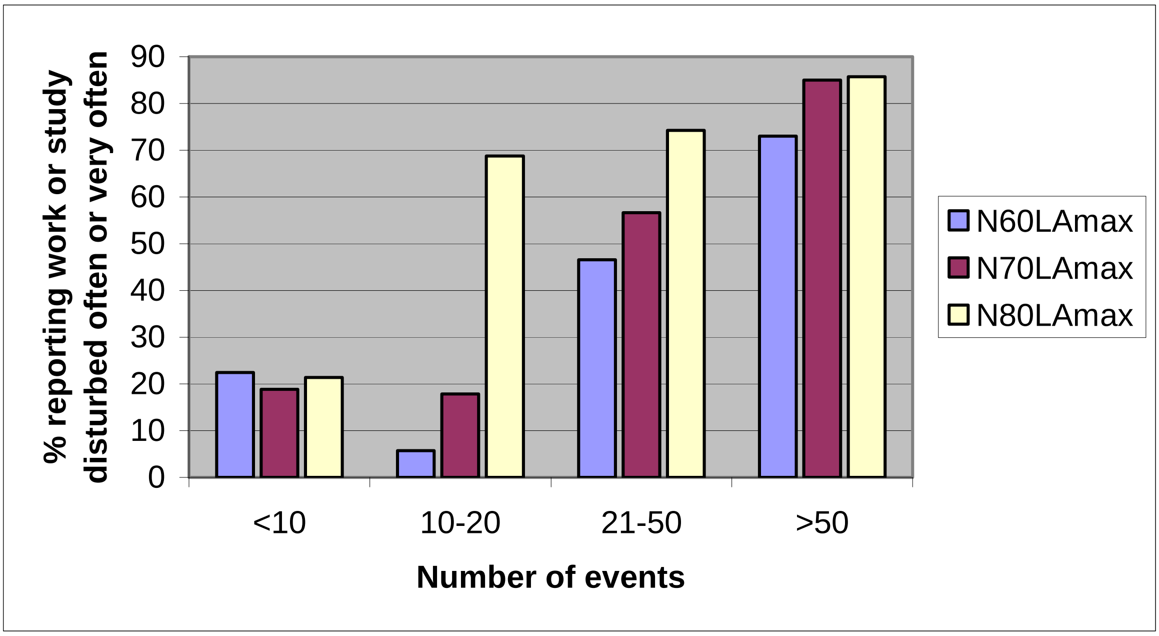


Figure 5.18: 12 hour N60, N70, N80 Work or study reported as being very often disturbed

5.2.7 WOULD CONSIDER MOVING REPORTED ACCORDING TO NUMBER OF EVENTS

The responses to the question whether residents would consider moving because of aircraft noise are shown in Figure 5.19 where it is evident that as noise level and number of events increases, the tendency to consider moving also increases. There is an affirmation with the $N80L_{Amax}$ case in the 10-20 events zone when compared with the other results where almost 60% of the respondents reported considering moving as opposed to less than 20% in the case of the $N60L_{Amax}$ and $N70L_{Amax}$ contours.

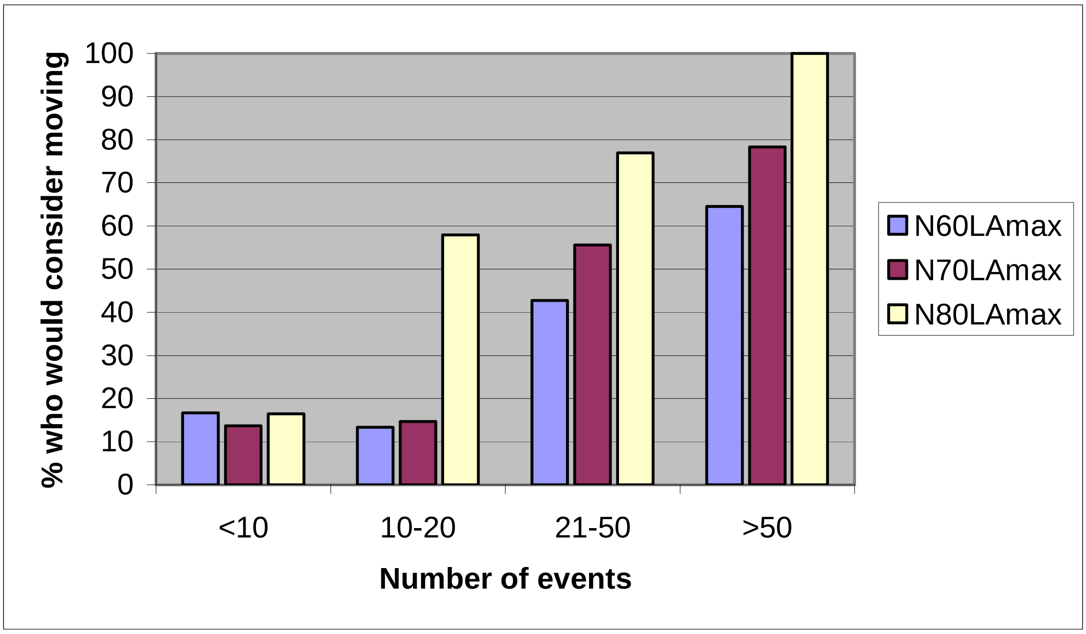


Figure 5.19: 12-hour N60, N70, N80 Would consider moving because of aircraft noise

In this chapter, it has been shown that supplemental noise information both in the form of a more tightly defined average energy noise time period (summarised in Figures 5.9 and 5.10), and number of events information (summarised in Figures 5.14 to 5.19) provide an important insight into the reported annoyance caused by aircraft noise, and interference of normal household activities from aircraft noise. The 'highly annoyed' and 'often and very often interfered with' occurrence of number of events above 80 at the level greater than 10 events is consistently above 50% which is to be expected given the loudness of this level. It is also an important finding that at the greater than 20 events level for N60, N70 and N80, (with the exception of work or study [Figure 5.18] and people who would consider moving [Figure 5.19]) over 50% of respondents are 'highly annoyed' and experience interference 'often and very often'.

In Chapter 6 an airport noise planning framework will be proposed. In devising such a framework, it is important that consideration be given to different factors which are important to residents. In Chapters 4 and 5, annoyance, interference with common household activities and the inclination of residents to move away from areas of aircraft noise disturbance were the factors which were discussed. The choice of these factors does not eliminate or diminish the importance of others. Based on the work of Blitch 1976; Brooker, Critchley, Monkman & Richmond 1985; Berglund, Lindvall & Nordim 1990; Fastl & Widman 1990; Staples, Cornelius & Gibbs 1999 and Aasvang & Engdahl 2001 these factors were selected. There is no universally recognised gold standard of measurement of aircraft noise, but there is consensus among people who live close to an airport's flight tracks that noise is an important aspect which has the potential to affect their well-being. The concept of this disturbance is not formally defined but any aircraft noise mitigation framework must take those factors which are important to residents into account.

CHAPTER 6: AN INCLUSIVE AIRPORT NOISE PLANNING FRAMEWORK

During the last two decades, the global environment has developed into the third major issue in world politics, the others being international security and the international economy (Elander & Lidskog 2000). The development of ideas and frameworks for environmental planning and development using noise as a focus is an evolutionary, historical and experiential course since the effect of the built environment on the quality of life on its residents is of growing interest (Dunstan et al. 2005). This has been the case in the United Nations Centre for Human Settlements, in the Habitat Agenda, and in information emanating from the Sustainable Cities Programme (Dahiya & Pugh 2000).

Airports which are located in undeveloped environments such as farming land, indigenous vegetation or arid land present no real noise problems. This is not to say that noise is not a problem for the relatively few people living in these environments and that aircraft noise should not be researched in these places. It should still be a priority to determine whether the impact of aircraft noise on humans and animals can be reduced and under what circumstances. Rather, it is the interaction of aircraft noise and land used intensively for commercial, industrial and residential purposes in urban areas that creates undesirable noise impacts for the greatest numbers of people. This has been clearly demonstrated in Chapters 4 and 5. In addition to being places where aircraft land and take off, airports are also work environments, terminal points for nodes of transport systems, and freight centres. In the absence of planning supervision, they will inevitably generate urban development in their vicinity. Development is most likely in the form of residential areas for employees working at the airport and commercial and industrial projects located near the airport. Land-uses associated with the airport are likely to generate secondary growth in the form of schools, shops and other functions associated with urban activity. Without land-use controls an airport will soon find that it indirectly spawns developments in its vicinity that are incompatible with its own function. Todes (2006) casts doubts on the existence of a strong urban spatial policy in South Africa, stating that policy has remained marginal and ineffective. It is also conceivable that if policy is strengthened, and land-use planning guidelines around airports are enforced, an airport's future growth will be constrained because of incompatible land-uses in its vicinity.

It is in this instance that the possibility of setting aside land for farming and preserving indigenous vegetation be considered. Farming already takes place to the north of the airport, within the noise contours. However, Breuste (2004) expresses a word of caution against the belief that establishment of indigenous vegetation is a simple matter: "…indigenous vegetation cannot be secured under circumstances in which most of the living conditions have completely changed inside the cities…" (Breuste 2004: 442).

This research has established that airport noise is a problem for residents living in areas surrounding ORTIA, particularly in areas close to the flight tracks. This chapter begins by looking at the growth prospects of Johannesburg as an urban area, as well as those of O.R. Tambo International Airport. Next, the necessity to plan for this growth in the context of aircraft noise will be examined at length. Finally, the role of aircraft noise prediction models in relation to land use planning and resident's feelings will be discussed.

6.1 GROWTH PROSPECTS FOR RURAL AND URBAN GREATER JOHANNESBURG

The question in this section is posed: What are the growth prospects for rural and urban areas in greater Johannesburg? Since there is not much rural land in greater Johannesburg, rural areas will be dealt with briefly. Greater Johannesburg's urban areas which comprise higher densities of residential land will be discussed in greater detail.

6.1.1 Rural areas

Rural areas often provide only limited economic opportunities for their inhabitants. A deterioration in infrastructure, service provision and employment opportunities in rural areas and the chance of a better life in cities however remote continues to attract migrants from rural to urban areas.

6.1.2 Urban Johannesburg

Johannesburg is at the core of the major metropolis of southern Africa. The ending of apartheid, and the re-integration of the South African economy into the world economy have led to increased business activity and to the physical growth of the city. Indeed, this urban area is experiencing growth in one generation that occurred in cities in some developed countries over several generations (Gleeson & Low 2000). Johannesburg's inaccessibility caused by artificial apartheid barriers to movement has been removed. As a key node for ever-expanding flows of traded goods, money and services in southern Africa, Johannesburg offers its citizens (who can afford it), consumption patterns drawn from nearly every geographical and cultural context. The range and variety of available goods results from a proliferation of tastes and because of this variety in lifestyle, Johannesburg lends itself to attracting more and more people. Growth prospects for Johannesburg are also determined, inter alia, by pull factors like water provision, services provision, economic growth, availability of job opportunities, and push factors like unpleasant living conditions in rural areas. Johannesburg also has a significant urban formal business sector providing wage employment, and this will continue to attract people to urban areas.

The rate of natural population increase in Africa's cities remains high despite the spread of AIDS (Rakodi 1998). Johannesburg is no exception. While growth figures for greater Johannesburg are not readily available, Gauteng, of which Johannesburg is a major part grew from 7.3 million to 8.8 million people (i.e. 20.3%) between 1996 and 2001 (Lehohla 2004). Johannesburg is an economic, communication and transport hub, and houses the seat of Gauteng's provincial government. Politicians, senior civil servants and business leaders live there causing public expenditure to be directed towards the metropolitan area, thereby making the area attractive to prospective residents and a likely choice for the location of transnational and domestic companies (Todes 2006).

It has been argued by Hall (1998) that electronic communication works, and will continue to work as an agent of dispersal. As the costs of telecommunications drop, activities should be free to locate away from central locations offering savings in property rents and/or purchases, and salaries. However, Hall (1998) also recognises that telecommunications are not costless and that linguistic and cultural boundaries and objections to technology create barriers to telecommunications services. Studies have shown that in metropolitan areas, the diffusion of information technology is more rapid than elsewhere, and that large cities will retain their key role as centres of economies. Gleeson & Low (2000) also refer to the role of new communication technologies. It is often claimed that new communication technologies slow the rate of entropy by reducing the need for air travel and transport of goods. However, this is disputed, given the power of these new technologies to reshape cultural horizons and encourage greater mobility by those who can now afford to travel. This is evidenced by three low-cost passenger carriers commencing operations out of ORTIA since 2004; namely 1time in 2004 (Rondganger 2004), Mango Airlines (Adams 2006) and Victoria International Airways (linking Johannesburg and Kampala) (D'Angelo 2006) and the Airports Company of South Africa having to double in capacity every nine years to handle the increasing demand from airlines (Bough 2006). This means communications technology alone cannot be relied upon to reduce air traffic movements.

Urban housing infrastructure is expensive to set up, and in a developing city like Johannesburg, spending on urban infrastructure will remain high. It is therefore of critical importance to ensure that the right residential planning is in place around airports to avoid planning mistakes which are almost impossible to fix in the future.

If Johannesburg's growth is set to continue, then the activities associated with the city ought to continue to grow too, one of which is air transport. The next section considers the growth prospects for the aviation industry.

6.2 GROWTH PROSPECTS FOR THE AVIATION INDUSTRY

The reason for the existence of an airport is primarily to move passengers and high value, low weight/volume freight over large distances by the fastest mode of transport, aviation. Air traffic in South Africa has grown at almost eight percent per year over the past five years (Bough 2006), and this growth is expected to continue. Land-use planning must take this growth into account since although aircraft are becoming quieter, aircraft noise levels will continue to increase with increasing aircraft movements.

Geldenhuys (2006) has recently reported on runway extensions and new runways. If the proposed developments go ahead, then the requirement for aligning town planning with those aspects of airport development which affect aircraft flight routes, namely runway position, length and orientation is highlighted. An important way for this to happen is to use the output from airport noise models to determine the noise impact.

Planners are faced with a number of paradoxes. If technological improvements result in a reduction in aircraft noise, too much land may be restricted from residential development. Technological improvements in aircraft range and efficiency (for example, the yet-to-fly Boeing 787 and Airbus A350) could mean that long-haul international flights go directly to other destinations instead of routing to Johannesburg as a hub from which smaller aircraft take passengers to their final destinations. This means that South African airports which currently do not have noise problems may develop them in the future. It also means that the noise problem is shifted from one place to another. Local authorities located near to smaller airports which presently do not have noise problems would be wise to conduct noise analyses using airport noise modelling tools, and to prepare land-use plans which take future aircraft movements into account.

Johannesburg, a world city in the making (Lo & Yeung 1998), is adopting more functions in the world-city system. Beavon (1998) believes that as South African cities (in Beavon’s case, Johannesburg, but also applicable to Ekhuruleni) come to grips with globalisation from their abnormal apartheid base, strong management will be required. The importance of airport noise models as a predictive tool for use by planning managers to plan for the future is highlighted. Gilbert et al. (1996) identify three critical issues for the world’s cities as to what is necessary for a concerted approach to urban sustainability namely governance, capacity, and actions and initiatives needed to secure sustainability. The aircraft noise issues around airports would have to be linked to the decision-making authority of planning authorities so that the airport noise problem is considered in the light of these issues.

In the present context of globalisation, cities are growth machines, and aviation will continue to grow to service this growth. Aviation is linked to the global capitalist economy, and its entropic logic of accumulation of wealth. Gleeson & Low (2000) argue that this growth is anti-ecological. Although noise is not as anti-ecological as, for example, a fuel spillage at an airport is on birds, animals and plants, it nevertheless can be regarded in the same way.

The next section describes the need for a spatial planning framework to plan for this growth.

6.3 URBAN PLANNING

The term 'urban planning' implies that some provision is made for future urban form to be well designed and functional. In the vicinity of airports, planners need to look beyond the basics of land allotment, so that those areas with the particular problem of aircraft noise can be pinpointed and dealt with. In the next section, the importance of a guiding framework is elaborated upon.

6.3.1 The need for a guiding framework

Harpham & Allison (2000) contend that the World Health Organisation's (WHO) definition of health – a state of physical, mental and social well-being, and not merely the absence of disease or infirmity is the most widely accepted. This holistic definition of health requires some interrogation of which physical factors influence health. An individual's health and well-being is a result of the physical and social environments impacting on the person. If the WHO definition of health is to be achieved, then a guiding framework is required. Concerning noise, what is needed are procedural and operational aims and programmes related to the goal of achieving a healthy acoustic environment which conforms with the goals of sustainability. This means that authorities, acting within broad-based community participation, set, and adhere to legal, institutional, organisational and action orientated directions for environmental enhancement and protection (Dahiya & Pugh 2000).

The process of governance requires an environmental framework which is relevant to the context of where the intervention occurs because the state does not operate in a vacuum. It operates where people and organisations associate for some objectives and compete for others. Dealing with the aircraft noise issue can be viewed in this context. Airlines and the airport wish to maximise their business investment by providing a rapid and safe transport service. Many citizens benefit from this service, but many others suffer from negative externalities of noise, manifested as expressed annoyance and interference with household activities as shown in Chapters 4 and 5. In pursuing what society has agreed to be good governance – in this case a reasonable expectation of a healthy acoustic environment around an airport – there must be some agreement on what is considered healthy. This will bring into focus that which must be done by society to achieve the objective. An ensemble of ideas included in the citizen's repertoire (in this case aircraft noise abatement and mitigation) includes a code through which society relates to its structure of authority (Harpham & Allison 2000).

Rakodi (1998) reports that when compared with many other African cities, Johannesburg's administration and services infrastructure is generally considered to be good, but there are aspects of planning and management which are weak and need remediation. Urban development that takes place outside a guiding framework leads to a deterioration in the quality of residential space and services. Rakodi (1998) reports on examples of deterioration as a consequence of lack of planning in Zaire, Sudan and Nigeria. In settlements in these countries, a large proportion of land development took place without any reference to a guiding framework. Resources that could have been used to ensure basic environmental standards for urban residents were not used to best effect. While aircraft noise is not generally regarded as a serious health threat, it may nevertheless still be regarded as an industrial residual which threatens the urban soundscape (Hardoy, Mitlin & Satterthwaite 2001).

6.3.2 Localisation

Localisation – the need for cities to find solutions to their own environmental problems – is inherent in urban and environmental programmes. A clear assignment of responsibilities among levels of government is required. To this end, the United Nations Council for Human Settlements (UNCHS) launched the Sustainable Cities

Programme (SCP) in 1990 (United Nations Sustainable Cities Programme 2006). The SCP focuses on sustainable development issues. While these are usually related to air and water pollution, 'dirty' production techniques, resource depletion, overwhelming urban growth and resultant inadequate infrastructure, aircraft noise is clearly an issue that has been shown in Chapters 4 and 5 that cannot be ignored.

To address these problems, the SCP is guided by a number of principles and viewpoints which can also be seen from an aircraft noise perspective (United Nations Sustainable Cities Programme 2006):

- The environment is a resource to be managed in a sustainable manner;
- Environmental problems cut across traditional administrative and organisational boundaries and must be addressed with new types of political and managerial action; and
- A successful response to urban environmental problems requires the active participation of all sectors of the community.

In establishing an effective environmental planning and management strategy, the SCP helps cities to:

- Identify and understand local environmental issues and establish priorities among such issues;
- Work out procedures and mechanisms for building consensus and developing co-operation;
- Develop up-to-date strategies and action plans that command widespread support;
- Implement strategies and convert action plans into projects and programmes; and
- Monitor and follow up the actions taken.

The foregoing examples from the SCP range from principles and viewpoints to establishing an effective planning and management strategy. Localisation leads to diverse understandings and feasibility in sustainability. Having public access to readily understandable aircraft noise information in the form of evening and night information and number of events noise information facilitates understanding and sustainability. Research agendas can focus on comparative evaluations with emphasis on identifying the underlying reasons for the options chosen.

A country's progress is dependent on creating and developing institutional and social capital. The air travel industry augments development patterns, and enhances the prospects of economic success. However, the aviation industry has a negative impact in the noise effects, as has been shown. This means that important social capital must be encouraged with a view to minimising the aircraft noise impact. Associational experiences of airport neighbours must be enhanced otherwise the disapproving reaction of the airport's neighbours can have a negative impact on air travel and the positive benefits air travel has on development.

Productive cohesion between aviation and residents is more likely when the rules of air travel go beyond safety and security to include dealing with noise through, for example contracts or agreements setting out responsibilities, assignment of costs, monitoring, enforcement of the rules and incentives for co-operation. Supplemental noise information lends itself well to these aspects as it democratises information. Environmentalism brings with it economic-organisational dilemmas, including corruption, apathy, the power of vested interests and administrative incapacity (Dahiya & Pugh 2000). If left unchecked, environmental concerns are trodden underfoot by the economic imperative.

6.3.3 Tensions in land demand

In a sense there is a tension in land-use planning between the land demanded by SANS 10103, and land demanded by prospective city residents, and developers. In Figure 4.13, the spatial extent of the $55L_{Rdn}$ contour clearly covers many residential areas and undeveloped land. If the $55L_{Rdn}$ contour is viewed as unachievable as a land-use planning goal because of its spatial extent, authorities may tend to ignore it, meaning that another limit must be sought. In areas which are already built-up, the $55L_{Rdn}$ contour as a limit for residential development is not achievable anyway. Dealing with these tensions requires good governance and development of capacity.

Governance embraces inclusiveness – the more inclusive the planning the more likely the outcome will be broadly accepted and appropriate than when affected people are excluded from decision-making. However, poorly managed moves to promote more inclusiveness can result in interminable discussion. Municipal leaders need to lead their local authorities by setting clear goals, in this case for land-use planning, and sticking to them. Capacity – the capability of local authorities to act in a town-planning role – is almost meaningless unless they have the facility to act effectively. A local authority must have the management, technical and fiscal capacity to act effectively in land-use planning when dealing with airports.

Meeting the challenges of sustainability in an urban context as suggested by Agenda 21 will require effective leadership by the elected local authority. Integrated transportation and land-use planning and local environmental assessments and audits should be carried out and action taken based on the recommendations. Harmonizing the development of urban areas with the overall system of settlements is a goal to be achieved (Dahiya & Pugh 2000).

6.3.4 Environmental Justice and Social Justice

Environmental justice is about incorporating environmental issues (including the less frequently considered issue of noise) into the broader intellectual and institutional framework of human rights and democratic accountability (McDonald 2002). The term 'environmental justice' encompasses the widest definition of what is considered environmental, and the present paper places people at the centre of the complex web of social, economic, political and environmental relationships (McDonald 2002). Environmental justice "…concerns itself primarily with the environmental *in*justices of these relationships and the ways and means of rectifying these wrongs and/or avoiding them in the future" (McDonald 2002). Locating a toxic waste site or an airport next to a poor community simply because it is poor is an environmental injustice that violates basic human rights.

In South Africa, the environmental justice movement has been able to attract a substantial following because of undemocratic decisions made in the past. The idea of social justice grew out of the close juxtaposition of great wealth and poverty in the early industrial city, and continues in the city being the site of constant struggles between conflicting groups (Gleeson & Low 2000). However, most environmental justice issues relate to forced removals, toxic waste and atmospheric pollutants. Social justice struggles were in large part, over the environment, and its qualities. Noise and noise from airports does not feature highly in the debates, but they do form a discourse which co-ordinates social action as argued by Habermas (1995) and Dryzek (1997).

It is worth pointing out that discourses are a set of shared assumptions and capabilities which enable the adherents to assemble bits of information that come their way into coherent wholes. They are a set of shared understandings. Discourses shape institutional arrangements – in this case governmental bodies responsible for land-use planning in the vicinity of airports. Within the social justice and environmental movements, it must be questioned whether the airport noise discourse in South Africa (to which Goldschagg 2002; Van der Merwe & Von Holdt 2005; and Van der Merwe & Von Holdt 2006; have contributed), has reached a level so that action is now taken. Chanda (2000) points out that noise pollution is the least documented environmental quality problem in the SADC region as evidenced by the lack of documented noise values in urban areas. Countering the problem of airport noise thrown up by competitive entrepreneurialism between airlines is increasingly being recognised by government to require national interventions. Airport noise is a contested concept and problematic in implementation, but the discourse has the potential to guide development in a benign direction. However, airport noise planning appears to be playing a supporting and apologetic role in urban planning which is increasingly dominated by a discourse of market co-ordinated competitive growth (Chanda 2000). This could be because airports in South Africa are not very busy yet – or certainly not as busy as airports overseas. Not one of South Africa's airports ranks in the top 30 busiest airports as measured by number of aircraft movements or passengers handled (Airports Council International 2006). It could also be because there are many other issues of pressing health urgency – HIV/AIDS, malaria and drug resistant TB and social needs (housing, water, sanitation) which beg attention. It could also be because the debate for reform in a market economy is split between protecting local business interests or protecting the environment, or because of the efficacy of the legislative and judicial procedure (McDonald 2002). Whatever the reason, town planning around airports must still be approached with caution so that the mistakes which have been made overseas are not repeated in South Africa and then have to be repaired in a costly manner afterwards.

The results of this study are an indication that airport noise constitutes an environmental threat and that there is some degree of consensus about the disturbance caused by aircraft noise in the evening and at night. This is a contrast to Chanda's (2000) view that the problem with noise is its general insignificance.

These concerns have translated into regulations dealing with noise. In the USA, Europe and other countries, despite the use of average energy noise metrics, perception of noise as a threat to overall quality of life remains strong. The local impacts of a new or modified source of noise pollution from aircraft can frequently lead to considerable debate and conflict (Moore 2000). What is lacking though is the legal requirement for data collecting and reporting. In the absence of strong regulations, totally supported introduction of new improved aircraft with quiet engines, comprehensive databases and evaluation and analysis of the impacts, communities feel annoyance at and experience interference with the impacts of these airport activities.

Moore (2000) offers two reasons why communities feel the way they do. First, the geographic context of the problem has been minimised, often to make the problem more approachable from the standpoint of bureaucratic control. This fragments the presentation of information about what is known and unknown. An average energy aircraft noise contour can appear to be quite small and be criticised for understating the problem. The use of supplemental noise in the form of number of events contours helps to reduce what is unknown. Comprehension of the problem, especially from a layperson's perspective, is difficult with average energy contours but made easier with number of events. People relate to the world around them, based on their knowledge, observations and perceptions integrated over the whole experience of life and not on environmental rules, regulations, procedures, policy analysis, and science designed under a conceptual framework. Supplemental aircraft noise information makes aircraft noise information available in a transparent way that is more easily understood by the layperson.

Secondly, the human dimension, as an essential element of the solution or at least mitigation of noise, has been minimised. Noise problems are often perceived by scientists, academics and regulators to be environmental and scientific in nature, requiring improved models, more environmental data, and better statistical methods in order to produce better decisions. These issues have consumed the energy of the process of studying airport noise and associated land-use planning while the ideas, values, positions, interests and beliefs of the affected public are far removed from the proceedings (Moore 2000).

To respond to these concerns, this dissertation presents a possible paradigm for local aircraft noise management which uses GIS-based technology to support land-use planning in which the community is involved. The approach conceives of the spatial and temporal challenges of achieving environmental equity as a regional planning problem. The argument is made that if environmental equity is a widely held regional goal, then fragmented approaches to risk management should be re-evaluated, and equitable solutions found that are community based.

Archibugi (2000) proposes a methodology consisting of a land-use resources matrix; identification of the appropriate territorial unit of evaluation; and the definition of indicators and for the various territorial units. A land-use resources matrix (LURM) can be constructed, on the basis of which available land resources can be determined. The purposes of the matrix are to estimate the availability or supply, and social demand for physical resources; and to evaluate the overall social costs and benefits of the consumption of land. The use of aircraft noise prediction models to inform this process is presented in Section 6.11.

In the urban environment, environmental disturbance in the form of aircraft noise pollution is between the demand for the use by urban activities and the supply of environmental resources. Problems arise when the same land unit may at the same time satisfy several demands and be in demand for several uses (Archibugi 2000).

The LURM constitutes an instrument for evaluating the opportunity cost of the use of a resource in terms of the advantage lost for alternative uses and provides a means of presenting decision makers with tradeoffs between costs and benefits for reaching justifiable planning decisions.

Archibugi's matrix rests on two conceptual entities: the supply of and the demand for limited space. This can be translated into land space around the airport. Examining the map will reveal certain open spaces, but these are covered by airport noise contours, where there is a demonstrably impact from noise. Should this land be developed? The LURM places the data on available territory on one side, and data relative to territory requested on the other side. The balance between territory requested and territory supplied is realised by means of the territory balance.

How can supplemental airport noise contours be useful in the urban planning process? Airport noise contours are an index, and like other indexes, they focus and condense information about complex issues for four aspects namely decision making, management, monitoring and reporting. The L_{Rdn} contour is prescribed by Standards South Africa but is complex. A night L_{Aeq} contour is slightly less complex in that there is no contentious time-weighted period and provides information related to when people are at home and disturbed by aircraft noise as has been shown in Chapter 5. Number of events above specified threshold contours provide supplemental information useful in decision making by residents, management by aviation authorities, and monitoring and reporting by airports. These different types of airport noise contours are part of an aggregation process of knowledge production to assist with decision making.

6.4 STATE OF THE ENVIRONMENT (SOE)

In terms of the South African constitution, everyone has the right to an environment that is not harmful to their health or wellbeing, and the right to have the environment protected for the benefit of present and future generations (South Africa 1996). The Department of Environment Affairs and Tourism recognised the difficulty in accessing information on the state of the environment and consequently started a state of the environment reporting initiative in the 1990s. These reports have been produced at different scales of analysis, namely national, provincial, metropolitan and local, as well as for different sectors, i.e. coasts, air, rivers, estuaries and catchments.

Ekurhuleni local authorities have compiled their SOE report (Ekurhuleni Metropolitan Municipality 2004) according to the Department of Environment Affairs and Tourism's national state of the environment reporting guidelines which follow the format of drivers, pressures, state, impacts and responses (DPSIR). Issues and descriptions have been presented according to environmental media, namely air, water, land and soils, and ecosystems and biodiversity. The definitions of the components of this framework are given in Table 6.1. The airport noise problem can

Table 6.1: DPSIR framework component definitions

Drivers	The human influences and activities that, when combined with environmental conditions, underpin environmental change. Indicators for driving forces describe the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns (e.g. population growth, poverty, mining, and industry).
Pressures	The pressures acting on the environment which result from human activities, (e.g. pollution of air, soil and water from industry, depletion of firewood through human consumption).
State	The condition of the environment including recent trends (e.g. level of air pollution)
Impacts	The consequences of the pressures on the environment (e.g. loss of biodiversity and ecosystem functioning, poor human health).
Responses	The societal responses to reduce or prevent negative impacts, correct environmental damage, or conserve natural resources, including legislation and policy, management strategies and programmes and initiatives

Source: Ekurhuleni Metropolitan Municipality (2004: 6) be usefully interpreted and investigated with this framework, and by incorporating the supplemental number of events aircraft noise information. An example of the DPSIR framework in terms of aircraft noise pollution is developed in Table 6.1 and Figure 6.1.

In the Ekurhuleni report, the issue of aircraft noise pollution is raised on five occasions, namely:

- "JIA is causing noise pollution in the surrounding residential areas especially Kempton Park – proposed residential developments here"; and possible solutions are mooted, i.e. "[c]hange flight paths, conduct thorough planning exercises considering relevant environmental legislation" (Ekurhuleni Metropolitan Municipality 2003a: 41).
- Chapter 5 makes reference to the detrimental levels of aircraft noise which residents of Greater Boksburg and Kempton Park are exposed to (Ekurhuleni Metropolitan Municipality 2003a: 122).
- Chapter 5 also includes a map of 24-hour cumulative aircraft noise contours which were produced in 2001(Ekurhuleni Metropolitan Municipality 2003a: 124) (No reference is made to explaining the nature of the noise or presenting alternative supplemental noise information.)
- Noise is highlighted as a critical area for monitoring and action (Ekurhuleni Metropolitan Municipality 2003a: 130)

In its conclusion the report is very brief in its treatment of aircraft noise, stating that "[n]oise issues related to air traffic need to be addressed in planning" (Ekurhuleni Metropolitan Municipality 2003a: 307).

Once the state of the environment is clearly understood, goals are set to deal with identified problems, so that the planning which is done can take these goals into account. The structure in which this is done is referred to as integrated development planning which takes place in a number of defined phases involving various role players as set out in Figure 6.1.

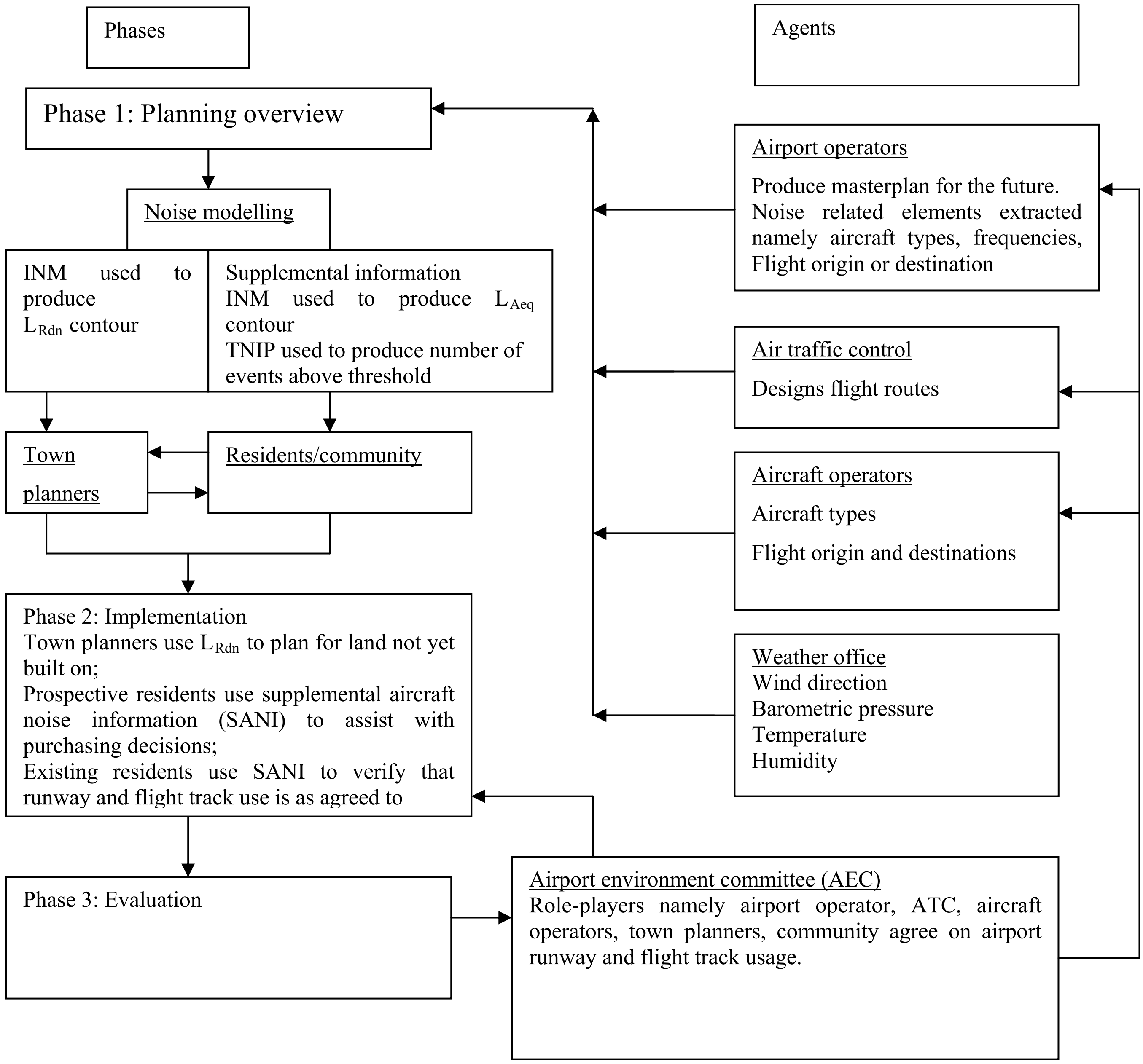


Figure 6.1: Example of the DPSIR framework in terms of aircraft noise management

6.5 INTEGRATED DEVELOPMENT PLANNING IN EKURHULENI

In terms of Section 25(1) of South Africa's Municipal Systems Act, municipalities must prepare and adopt their own integrated development plan (IDP) which outlines the future planning direction of the municipality, and embraces the needs of the community (Ekurhuleni Metropolitan Municipality 2003b). The IDP must contain the following core components:

- A vision for the long-term development of the municipality;
- An assessment of the existing level of development in the municipality;
- Development priorities and objectives for the elected term;
- Development strategies;
- A spatial development framework;
- Operational strategies;
- Applicable disaster management plans;
- Financial plan and budgets; and
- A performance management system with key performance indicators and targets.

The IDP recognizes the importance of ORTIA as bourne out in the following two quotes from the IDP:

- "JIA, Africa's largest airport, is the entry point for most foreign visitors to Southern Africa. During the 1999/2000 financial year, R475 million was spent on expanding its facilities. Approximately 450 flights daily, or one every three minutes, carry an annual total of 6,2 million departing passengers and 350 000 tons of freight. The airport attracts significant secondary activities to the area, such as manufacturing and warehousing" (Ekurhuleni Metropolitan Municipality 2003b: 7).

- "The triangular area around ORTIA represents a core focus area for Ekurhuleni. Large portions of land to the south and east of the airport offer potential for future development or re-development. These developments could be used to establish and promote the identity of Ekurhuleni in future. The agricultural holdings of Boksburg directly to the south of ORTIA, in

> particular, have the potential to be developed in such a way" (Ekurhuleni Metropolitan Municipality 2003b: 19).

The airport is also part of the Gauteng Provincial Government's (GPG) Blue IQ project, the economic infrastructure development programme of the GPG. It is investing an initial R3,5 billion of provincial government funds in creating or upgrading strategic economic infrastructure to kick-start 11 major projects to be driven by Public Private Partnerships. "This project is the first, joint private sector, government-led IDZ and involves upgrading the airport and further developing manufacturing and exports. Government wants to encourage the private sector to invest in the projects, which will include an industrial development zone for light manufacturing and high-technology production; and infrastructure for the IDZ site" (Ekurhuleni Metropolitan Municipality 2003b: 19).

What all this portends is that air traffic to and from the airport will continue to grow and as a consequence, noise from aircraft will continue to increase. The importance of taking aircraft noise into account in planning is therefore emphasised.

Ekurhuleni has adopted a Spatial Development Framework (SDF) as part of their IDP. The SDF proposals deal with how the future land development strategy should be structured by addressing the following (Ekurhuleni Metropolitan Municipality 2003b):

- Implementation of an urban development boundary (UDB) ;
- Peripheral land-uses;
- Extensive agriculture;
- Activity nodes;
- Infill development priority areas;
- Strategic development areas;
- Service upgrading priority areas;
- Regional open-space system;
- Mining; and
- Transportation.

The SDF recognises the creation of an urban development boundary (UDB) declared by the GPG (see Figure 3.6). The UDB limits the type and extent of development outside of this boundary in the future. The boundary is designed to limit urban sprawl and protect agricultural land. This poses the question should land be sterilised for development near the airport, would this have consequences for land outside the airport boundaries? Within the UDB, land-use must be consistent with existing plans, legislation and normal procedures. The SDF makes the point that development rights within the UDB will not be automatically guaranteed in the future, and that outside the UDB, rural land-use is more desirable.

ORTIA is part of one of four main core areas, known as activity nodes. The triangular area around the airport is a core focus area for Ekurhuleni. Large portions of land to the south of the airport offer the potential for future redevelopment. The agricultural holdings in Boksburg to the south of the airport are singled out as having the potential for possible future development.

Eight major precincts have been identified in the SDF for future residential expansion. Of these, the Esselenpark/Kaalfontein area which forms part of the Tembisa-ORTIA corridor, Pomona/Benoni North (area northeast of ORTIA); and Boksburg South lie in areas where there is potential for aircraft noise disruption. It is important that these areas receive particularly careful consideration of the aircraft noise impact, and that consideration be given to using supplemental aircraft noise information in the planning process.

The responsibility for ensuring that the Ekurhuleni region develops according to the guidelines in the SDF lies with the municipality's development planning department. They are required to manage conflicting aspects of spatial development. Land-use management and spatial planning are key performance areas for this department. Air quality monitoring and the rehabilitation of damaged environmental areas are mentioned, but noise and specifically aircraft noise are conspicuously absent.

Under the transport theme, the SDF places emphasis on improving the services provided by the taxi industry and bus companies but the airport is only discussed in the context of how Ekurhuleni can exploit its spatial proximity. The impact of the growth of the airport is not mentioned, nor the probable future aircraft noise impact resulting from this growth.

The health and social development sections of the SDF are also silent on the issue of noise. Primary health care rightfully receives priority, particularly given the challenges of TB, HIV/AIDS and maternal health, but in an area where a large airport already exists, and which is going to get bigger and noisier, some mention of dealing with the noise impact would be prudent. This leads to the subject of applying sustainable development principles to the noise issue.

6.6 GUIDING PRINCIPLES FOR SUSTAINABLE URBAN DEVELOPMENT

Many guiding principles for sustainable development which are already in use and have gained widespread acceptance have also increasingly found their way into legislation and instruments of policy. Four of these principles gleaned from Haughton & Hunter (1994) are put forward here as starting points for a debate on the necessity or not of aircraft noise information.

6.6.1 Prevention is better than cure

This principle stresses the importance of a precautionary approach to urban development; environmental impact assessments must be conducted on all major development projects. The principle advocates that unless people clearly understand the environmental impacts of their activities, they should refrain from activities which may potentially damage the environment. The difficult challenge is to prove that an activity is not environmentally damaging. The answer to this is that some form of rigorous investigation needs to be done of the likely environmental implications of a particular activity prior to its commencement. This, however, is not adequate in itself, as it is also the interrelationships of activities that need to be assessed. Aircraft noise may be a disturbance and the current means of assessment – a 24-hour average – may not describe the night-time disturbance adequately. One is to prevent activities from commencing in the form originally envisaged. Aircraft noise carries a personal risk to health rather than an environmental risk. Risk-taking is a necessary part of human existence, but it is an activity which requires continual questioning of the degree of acceptable risk. Providing citizens with aircraft information in the form of number of events at different levels will enable them to evaluate the extent of the problem. It will enable air traffic control to evaluate the consequences of routing aircraft one way or another, and airlines to understand the noise consequences of their flight decisions.

The related question arises as to who decides on the acceptability of noise? Affected residents probably have a lower threshold for acceptability – airlines in their attempt to maximise use of capital equipment probably have a higher level. It is unlikely that it will be beneficial that development decisions are left solely to the wishes of any single grouping.

6.6.2 Nothing stands alone

Account should be taken of the local, regional and global implications of urban activities and urban environmental policies. Individual pollutants may combine in the environment to produce more severe effects than their individual effects may suggest: the synergy (cumulative effects) problem. While it is important to consider aircraft noise around an airport, the question may be raised about other noise sources like road traffic. Road vehicles and aircraft give off noxious gases which have immediate health consequences for people exposed to them, as well as longer term consequences in the form of global climate modification. The key point is that airports can exert profound direct and indirect impacts on the surrounding environments, and it is important that policy-makers attempt to understand these consequences in order to minimise the creation of undesirable impacts. Aircraft noise contours have the ability to inform city managers and local authorities about these problems.

6.6.3 Identify and respect local, regional and global environmental tolerances

This principle ensures that urban development is sensitised to its capacity to interact with and alter capacities to cope with environmental disturbances. It is related to the ‘nothing stands alone’ axiom. There exists local variability in the capacity to accept and adjust to environmental disturbances. For example, in a developing country like South Africa, in order to promote economic development and reduce unemployment, it may be necessary to accept higher noise levels if it means creating jobs. Supplemental aircraft noise information contours can then be used to study where the problem is at its worst, and attempt to minimise its impact. At the urban level, aircraft may be routed via areas best able to cope with noise pollution.

6.6.4 Enhance environmental understanding through research

This precept ensures that complex environmental and economic interdependencies are better understood as a basis for informed decision-making. Ranging across all of the principles discussed in this section is the need to understand environmental processes better. Night-time noise contours, and number of events contours will help people to understand the environmental and social consequences of aircraft movements. The requirement is to create new indicators for environmental protection. Dissemination of this improved knowledge is an important element in refining the decision-making behaviour of individuals, aviation related companies and local, provincial and national government.

6.7 PRINCIPLES FOR REDUCING AIRCRAFT NOISE SUCH THAT A SUSTAINABLE URBAN NOISE ENVIRONMENT IS PROMOTED

Once the areas which are, or could be affected by aircraft noise have been established, a number of principles for reducing aircraft noise can be implemented. These are discussed in this section.

6.7.1 Appropriate technology, materials and design

Technological solutions to aircraft noise can be expensive and create problems which ordinary people cannot understand or implement themselves. It is very difficult and expensive to insulate an existing house from aircraft noise and the dwellings in Tembisa (Figures 4.6 and 4.11) would be almost impossible to insulate. A simple yet effective remedy is to locate houses far away from airport flight routes.

6.7.2 New indicators for noise environmental health

There is a need to broaden the way people measure their acoustic well-being. The well-being of people should also take into account the noise they are exposed to. Improved knowledge of the aircraft noise environment can be valuable to residents in decision-making, for example should they move into an area affected by aircraft noise? Supplemental aircraft noise information would go a long way to providing information which laypersons could use to decide whether the noise levels are acceptable to them and whether they want to choose to live in that place or move.

6.7.3 New indicators for environmental productivity

A whole life-cycle audit of the aviation industry can highlight where unnecessary noise generation occurs and assess the potential to reduce these. The number of events above a threshold contour is a good example of this.

6.7.4 Acceptable minimum standards through regulatory control

The extensive use of regulatory controls creates the problem of diminishing returns. It is argued that countries reach a point in their direct use of regulation where the efficacy of these regulations declines. It cannot be said that this has happened in South Africa yet. Legislation, or national standards, are merely pieces of paper. To successfully transform the aircraft noise environment in neighbourhoods around airports requires community will and support, and an effective programme of implementation. Countries which are signatories to ICAO have been phasing out old noisy aircraft and banning the addition of these aircraft to airline fleets.

6.7.5 Internalise environmental costs into the market

The essence of this principle is the ‘user pays’. The market needs to be made to work for the environment by moving away from the situation where polluters can abuse the ‘free goods’ of the natural environment.

6.7.6 Social acceptability of environmental policies

It is difficult to ensure that all parties agree on what constitutes an acceptable aircraft noise environmental management policy. This survey has confirmed that those people who live closest to the flight tracks followed by aircraft are the most disturbed by aircraft noise. The use of supplemental aircraft noise information will at least help people to understand the problem.

6.7.7 Widespread public participation

The Australian experience has shown that average energy contours do not provide enough information, and because of their complexity they are often misunderstood and mistrusted. Supplemental aircraft noise information will assist in providing the public at large with more easily understandable information and thereby improve participation, decision making and planning.

6.7.8 Subsidiarity

The responsibility for the implementation and management of urban environmental programmes must rest at the appropriate level of government. Subsidiarity implies the decentralisation of power and responsibility to the lowest level of government possible – to the level where people who are more affected by noise can appeal to have something done about it. A key issue though is how effectively government at the lowest level can function. The level of policy formulation may be at national government level, but the realisation of the policy will be at local level. Because aircraft move rapidly over long distances, and the same aircraft may appear at airports within the jurisdictions of several local authorities in one day, control of that aircraft's noise by local authorities is not feasible. National government is therefore most suited for this and not subsidiarity. The principle of subsidiarity may, however be applied to the land-use management around those airports where the aeroplane flies.

6.7.9 Flexibility in devising and implementing environmental policy

In the search for appropriate policies to enhance the noise environment, there is a danger that too much reliance will be placed on one particular means of representing aircraft noise. This could be said of SANS 10103 and 10117. Given the wide range of the urban aircraft noise problem, and the dynamic nature of urban areas, a flexible approach to representing aircraft noise is required. Average-energy aircraft noise contours are complex to understand especially given the tendency to obscure particularly noisy events at noise sensitive times. Therefore, rather than try to use one instrument derived from a particular principle, it is more likely to be fruitful to consider using the number of events noise descriptor as well when responding to a set of interacting and changing aircraft noise problems. Flexibility also encourages experimentation and innovation to emerge and guide the next generation of policies. Sensitivity to the peculiarity of place is also encouraged by innovation. The need for continuing research into finding the most efficient combination of aircraft noise contours and information is emphasised.

6.7.10 Long-term strategies are necessary for environmental management

Aircraft noise contours and urban land-use planning can promote a long-term intergenerational equity meaning that future generations do not have to suffer the consequences of bad planning of the present. Average energy noise contours are useful to assist with considering the long-term development of urban areas and the wider region. A strategic long-term vision for cities should be to enhance the quality of life for present and future residents. To do this around airports, mitigating and managing the environmental impact of aircraft noise should be prioritised.

6.7.11 Improved co-ordination across environment-related policies

There are many aspects to the quality of life of urban areas. These need to be brought together under the principle of improved co-ordination of environmental policies. A well-defined, clearly identifiable authority should have responsibility for overseeing the formulation and implementation of such a vision. At national level, policy should be formulated, and at local level it should be implemented. Identification of the appropriate level of responsibility is critical. This means that the work of traditionally separate departments within local government needs to be brought together more consistently. Strategies should maximise co-operation between departments to use local knowledge and initiatives and integrate the policies of different departments and maximise the existing and potential complementarities.

Land-use planning decisions around airports should be based on a local development plan agreed to by local government departments responsible for that area, as well as the local community and local business interests. Airlines should also be kept informed and consulted since they are the ones responsible for creating the noise. Private companies in urban areas may have much to offer local authorities. For example, around an airport freight forwarding and courier companies may be encouraged to move into areas considered unsuitable for residential development due to noise.

6.7.12 Non-discrimination and equal right of hearing

Although more commonly referred to in issues of transboundary pollution (eg. climate change), this would ensure that aircraft noise pollution issues could be resolved by all those affected on a basis of equal rights. Previously, in South Africa, during the apartheid era, land-use planning was racially based. Although these policies are no longer in force, their land-use planning consequences are still very much in evidence and will be for many decades to come. The equal right of hearing provides citizens with the basic right to be heard, no matter what their race or their location. The survey results from the township group clearly indicated an awareness of aircraft noise and resultant annoyance and interference. Local urban development proposals which will have adverse impacts, including new airports, or changes to runways which will change the noise patterns around airports, should be subject to consideration on an equal basis by all those who may be affected.

6.7.13 Need for better availability and understanding of environmental information

The awareness of aircraft noise issues needs to be continually heightened amongst the community around an airport, government agencies, and the aviation industry to achieve the most from urban environmental management and to encourage a more responsible attitude to acoustic environmental quality. This heightened awareness requires a right to freedom of information on the impact of aircraft noise on developments, and education and advice for noise producers, and those who are affected. Number of events aircraft noise information provides a means of raising aircraft noise awareness.

In order for the marketplace to work effectively to reduce aircraft noise environment consumers (passengers and freight forwarders) need freely available information on the noise environment friendliness of aircraft. This is something which airlines will start to take seriously in recognition of the search for the 'acoustically green' consumer, and in the face of increasingly tight governmental environmental regulation. In South Africa, governmental regulation of aircraft noise is still very lax. However, some aircraft operators have taken steps to renew their fleets with quieter aircraft. Admittedly, major factors are the high fuel and maintenance costs of noisier old generation aircraft, but if airlines are forced to consider phasing-out noisy aircraft and are not permitted to add these to their fleets after agreed-upon dates, then this would help to bring South Africa into line with ICAO guidelines which have been enforced in Europe and America.

The continual monitoring, evaluation and synthesis of aircraft noise information at local and national level is an important environmental management tool. Average energy and number of events aircraft noise audits can aid the identification of aircraft problems and the prioritisation of action plans and policies. National governments should monitor the compliance of airports and local planning authorities with quality standards and allocate resources effectively to neighbourhoods with pressing aircraft noise problems.

6.8 POLICY INSTRUMENTS FOR IMPROVING THE AIRCRAFT NOISE ENVIRONMENT IN AN URBAN SETTING

The previous sections concentrated on principles for sustainability in the aircraft noise and urban environment. Putting the principles for sustainable urban development into practice requires a complex inter-weaving of different approaches and different urban requirements. Haughton & Hunter (1994) condense these into six categories; namely legislative, technological, economic, planning, local enablement, and education and information. The approach in this dissertation favours the technological, planning, and education and information categories, while recognising that the others also have their role to play. A combination of these approaches usually brings about more rapid and effective change than used in isolation.

6.8.1 Environmental impact assessment and integrated environment management mechanisms for airport noise management

Environmental impact assessment (EIA) provides a framework for assessing the potential impacts of developments so that adverse environmental effects can be eliminated or minimised. An EIA may also cover the noise from aircraft, and noise contours are the mechanism to represent, visualise and study the problem.

Airport noise contours may be used in three key ways. Firstly, when a new airport is being planned, secondly if there are changes planned for an existing airport (new runway, lengthened runway, new aircraft types), and thirdly to evaluate the impact of an existing airport's operation. The first two would be incorporated into an EIA study, while the third would be part of integrated environmental management (IEM).

Most forms of EIA attempt to do three fundamental tasks:

- Identify the nature of the induced activities which are likely to be generated by the project;
- Identify the elements of the environment which will be significantly affected; and
- Evaluate the initial and subsequent impacts.

An IEM plan should be concerned with the management of the beneficial and adverse impacts which are generated by aircraft noise.

6.8.2 Economic policy instruments

6.8.2.1 Potential of economic policy instrument to reduce noise

The potential of economic instruments to foster improvements in the airport noise environment has been increasingly recognised. The economic instruments are informed by the noise contours produced either from calculated noise contours, or by measured noise contours. Use of aircraft noise contours enables state decision-makers to take account of positive and negative environmental externalities. For example, constructing an airport may raise nearby property values for some land-uses (for example warehousing) but decrease them for residential users. Aircraft noise contours can provide an indication of the cost incurred when making noise, and allow producers and consumers rather than regulators to decide how to alter their behaviour to meet environmental needs. This has a number of beneficial consequences: freedom of choice is not constrained; those who find it cheaper to make less noise will make the biggest reductions; there will be an incentive to develop quieter flight procedures or take into service quieter aircraft; and there is a continuing incentive not to misuse the environment.

There is intrinsic value to looking at applying economic instruments to dealing with aircraft noise in an urban context since many of the aircraft noise problems in cities are what economists call non-costed environmental impacts. For example if a residential dwelling's value is reduced because of aircraft noise, does the noise maker pay compensation to the dwelling's owner? The instrument must be capable of attaining its environmental objectives in a reliable and consistent fashion. It therefore needs a way of assessing the objective, and aircraft noise contours are one way of doing this.

6.8.2.2 Limits of economic policy instruments

In attempting to make the market work for the environment, a concern is to ensure that the market takes account of all environmental costs, risks and benefits. For example, reducing noise often leads to an increase in emissions which pose a more immediate risk to the environment, climate and health. Another problem is that the information base for producers and consumers is never likely to be sufficiently reliable or widely available. There is still incomplete scientific understanding of aircraft noise – its propagation, transmission, and the annoyance and interference it causes. Aircraft noise contours are time-consuming and costly to calculate and disseminate, and can only provide a snapshot of the noise around an airport for the time period they represent. Although it is an inexact science in the ways reported above, it is argued by the author that to approximate and move towards improving using aircraft noise models as a tool for introducing economic tools, society is at least attempting to move forward rather than ignore the problem.

Key aspects of adopting an economic policy are a noise tax, a limit on the types of aircraft flown, a phase-out or a non-addition rule. A noise tax may be socially regressive in South Africa since older, noisier aircraft which are cheaper to buy, can be used to transport passengers who previously could not afford to fly. The tax would hinder the stimulation of business and the economy is therefore hindered (Haughton & Hunter 1994).

Policies make a marked difference to rates of economic growth, and to the environmental conditions and quality of life in cities. Sustainable development then becomes a debate about urban policies and how to shape and implement these policies for the abatement of environmental (noise) degradation. Development policies that achieve growth and social development improve incomes and expand social opportunities. However, these improved incomes and social opportunities also place a burden on society. The airline market creates better transport opportunities, but high-quality public administration must be created which serves the general public interest, in this case understanding and dealing with noise impacts.

In the next section the role of noise prediction models will be discussed.

6.9 AIRCRAFT NOISE PREDICTION MODELS AND NOISE CONTROL STRATEGIES

Apart from land-use planning, the INM and TNIP aircraft noise prediction models can be used to study operations on and in the vicinity of an airport, and to modify these to control noise and decrease its impact on airport neighbours. In this section, noise preferential runways, minimum noise routings and noise insulation and land purchase are discussed.

6.9.1 Noise preferential runways

Conventionally, aircraft are operated into the wind on landing and take-off so that the crosswind and tailwind component is minimised and operations made safer. Modern aircraft are not particularly sensitive to the crosswind and tailwind component. Consequently, landing and take-off operations can be carried out on a less than optimally orientated runway, if that facility will reduce the noise nuisance to the community. This is known as a noise preferential runway. Noise prediction models can help planners to visualise the impact and assess whether there are gains to be made for the community at large.

6.9.2 Minimum noise routings

Related to the noise preferential runway concept is that of minimum noise routings which are designed to direct arriving and departing aircraft to follow routes over areas of low population density. The size of the impact of the noise footprint is not altered, but the impact in terms of the size of the disturbed population is lower. The place of noise prediction models in this instance is to model different options and implement those with the lowest population impact. Town planners must ensure that the identified low densities are kept that way, and air traffic control must retain those routes for which land-use planning has been done. The work of Von Holdt (2003); Van der Merwe & Von Holdt (2005); and Van der Merwe & Von Holdt (2006) have potential here.

6.9.3 Noise insulation and land purchase

Sound insulation can provide some relief from aircraft noise albeit an expensive option. In some countries, residents affected by defined levels of aircraft noise nuisance are eligible for grants which must be used for sound insulation procedures. Noise prediction models can be used to initially identify which buildings may qualify. An even more expensive option of reducing noise nuisance may be adopted where buildings in the immediate vicinity of the airport may be purchased by the authorities and their use converted to something more compatible with noise.

6.10 PROVIDING AIRCRAFT NOISE PREDICTION: AVERAGE ENERGY AND SUPPLEMENTAL AIRCRAFT NOISE INFORMATION

It has been raised elsewhere in this study that average energy aircraft noise information, while useful for land-use planning does not provide sufficient information for residents affected by noise seeking to understand the problem and minimise their exposure. It is a key recommendation of this study that supplemental information be provided to these residents. For example, consider a residential property where the occupier has a problem with noise. The amount of aircraft noise that location will be exposed to according to the L_{Rdn}, night L_{Aeq}, and number of events above specified threshold values can be determined. Authorities may agree that there is a problem and attempt to deal with the problem (e.g. through noise sharing).

6.11 THE AIRPORT MASTER PLANNING FRAMEWORK AND SUPPLEMENTAL NOISE INFORMATION – A COLLABORATIVE PROCESS

Although not a requirement in South Africa yet, airport owners usually create a master plan to provide a framework for future development. The master plan assists management in making short and medium term decisions without compromising the options for future long term development. Master planning should incorporate collaborative planning – as has been successfully used by the United States Department of Transport (Morgan 1999) - by including all the role players (including airport neighbours) so that trust is enhanced and relationships and networks are forged. Rapid urbanisation can be expected to continue in South Africa resulting in land use planning conflicts. One such conflict which will create ongoing problems is the encroachment by residential land in airport locations creating ongoing problems with noise from aircraft in residential neighbourhoods. Providing supplemental noise information in the planning framework will present an opportunity for communities to get involved in the process and participate in the discourse at a level at which they can freely engage. Moote, McClaren & Chickering (1997) divulge that if the full range of the public's needs and concerns are not addressed, and in terms they understand, the consequences are that the general public feel they have no alternative but to resort to appeals and lawsuits to block implementation of land use planning.

Doyle (1998) and Morgan & Mitchell (1998) add that an airport can be made compatible with its neighbours if management has the following characteristics:

- A belief that a problem exists and can be resolved.
- A belief that occupants of the environs are constituents of management on an equal footing with users of the airport.
- An approach to the situation that is open, fair, and objective.
- A willingness to consider any and all possible alternatives.
- The ability to compromise towards a consensus solution if necessary.

It is unlikely that there will ever be unanimous agreement for the airport operation options chosen, however making supplemental aircraft noise information available in the airport master planning framework through a collaborative approach will demonstrate that management are sensitive to the concerns of the community and the community will respond by being more sympathetic to the airport's needs (European Transport Forum 1995).

6.12 CONCLUSION

This chapter has identified a wide range of guiding principles for aircraft noise which when used together may help urban residents, the aviation industry and government to contribute positively to providing attractive urban environments and intergenerational urban sustainability. It has been demonstrated that using supplemental aircraft noise information within a collaborative approach framework is essential for the layperson to grasp the issues around reporting aircraft noise and that for transparency, the information supplied should be comprehensive.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS.

7.1 SUSTAINABLE DEVELOPMENT AND URBAN POLICY

The concept of sustainable development is a useful one because it creates links between different sectors, and highlights potential synergies and conflicts between different goals (Hardoy, Mitlin & Satterthwaite 2001). Sustainable development at its core is about reconciling the use of resources and the generation of waste with the capacity of the environment to absorb and break down wastes and render them harmless. This idea is more commonly applied to air and water pollution, so the dilemma with aircraft noise is that it may not be seen in this context and the problem is not regarded as being so severe. Aircraft noise can be regarded as falling outside of the mainstream of concerns about the environment.

However, there is evidence from the survey in this research and research done elsewhere that aircraft noise is a problem which can, and has generated conflict in localities where airports and citizens are in close proximity. For example, 33% of respondents reported being highly annoyed with aircraft noise. The concept of sustainable development makes society think about the environmental implications of human activity – in this case, the waste product being noise generated by aircraft, but it could also be the decision to build houses and airports at distances which are inappropriately close together.

A quiet soundscape is a natural resource which is difficult to protect within a market economy because economic transactions allocate little or no value to quietness. For instance, every time a noisy Chapter 2 freight aircraft takes off over a residential neighbourhood at 03:00, noise is generated which disturbs sleep. But no ‘price’ is paid towards the cost of awakening people although some governments have been considering, even implementing, noise-based pricing to adjust for the cost of people being woken. Revenue generated in this way is used to fund noise insulation programmes at some airports in America and Europe. Detailed understanding of the adverse effects of aircraft noise disturbance is still being sought.

The environmental debate has changed from the specific preservation of natural areas to environmental planning for sustainability. However, because much of the discussion on sustainable development has concentrated on ecological sustainability (e.g. forests and fisheries), town planners and others involved in dealing with aircraft noise have not fully explored the possibilities that the sustainable development ethos has to offer. Indeed, greenhouse gas emissions and the depletion of the stratospheric ozone layer have taken on much of the discussion. The discourse has more recently started to focus on the unmet needs for water, sanitation, health and nutrition requirements of millions of urban and rural dwellers. These are pressing problems which require urgent successful solutions. But what of the areas where gains are being made? What problems presently regarded as minor are going to become the major problems of tomorrow, and how should we be looking ahead to avoid having to undo costly mistakes?

The threats to the natural soundscape beg the question: What limits should be set, and what criteria apply? In Chapter 2 it was clearly shown that four sets of noise contours with very different spatial characteristics could be produced from one set of aircraft movement data. If there was more time available an even greater number of contours could have been produced, with different noise sensitive time and associated noise weightings. Does sustainability require a reduction in the number of flights, or can it be achieved through removing the noisy aircraft? Should draconian measures be taken to remove residents who are most exposed to aircraft noise? The answer to these questions is that it is possible to implement these, but at a cost to business and other air travel which in turn would have severe consequences for the economy.

Global aircraft noise problems were, to a great extent, dealt with in the First World by phasing out noisy aircraft in 2002. In fact, in accomplishing the phase-out many airlines headquartered in developed countries sold off their offending aircraft to airlines in less-developed countries which were not required by their governments to comply with these regulations. So while urban noise environment sustainability in the First World was enhanced, on a global scale, the noise just went elsewhere. It is unclear from ICAO phase-out guidelines at which scale sustainability was being sought.

To tackle such issues, adequate policy measures at different levels and sectors of state and society must be sought. Strong national policies must be developed and local government must take responsibility as co-ordinator, facilitator, and enabler of environmental policies and strategies. Central to these roles are the development of strategies '… which bring together actors and agencies at local, national and international levels, across public, private and voluntary sectors" (Haughton & Hunter 1994: 300). Aircraft noise is not the immense environmental problem like climate change or ozone depletion, but, like these problems, it is linked to the value-systems of people in their daily lives (concerning consumption and transportation, for example) and is "… becoming a main arena for the implementation of green policies" (Elander & Lidskog 2000: 44). Therefore, with regard to the question of aircraft noise, the remedies are also located in the streets and suburbs where people spend their lives.

The urgency of the aircraft noise problem posed in the introduction has in no way diminished. Indeed, more recent research argues that the noise problem continues to worsen (Eagan 2006; Morimoto & Hope 2005). Eagan (2006: 6) contends that "[c]ommunity expectations of continued decreases in noise levels may not reflect the reality of the extended time frame required for development and adoption of advanced technology for the next generation of quieter aircraft" and Morimoto & Hope (2005: 165) report that "[t]here is increasing concern about aircraft noise as a result of the rising demand for air transport".

Sustainable city development at present has become commonplace in the policy goals set by politicians. National government provides the leadership, but decentralises the implementation to the local authorities by diversifying responsibilities. Hardoy, Mitlin & Satterthwaite (2001) query the ambiguity in the term sustainable development. For a town planner, sustainable development is reflected in the need to design livable urban areas. For an airline and an airport however, it may refer to the need to sustain profits and returns on investments. One of the ways in which the progress of capitalist expansion can be read is by the rise in air traffic. Consequent aircraft noise disruptions threaten urban areas close to airports. The dynamic of social deprivation in rural areas (relative and absolute) can be expected to catalyse further migrations to wealthy heartlands, requiring even greater diligence on the part of urban planners.

The result of the phase-out of Chapter 2 aircraft in Europe and North America has generally meant a shift to, and an increase of these aircraft types, and consequently noise, in the developing world. It is necessary today "… to act to change the global context of local action" (Elander & Lidskog 2000: 45).

Urban environmental sustainability cannot be perceived without social equity and economic sustainability when environmentally sustainable development is being defined more as a process and not as an endpoint. Supplemental noise analysis democratizes knowledge by operationalising the notion of sustainable development.

The author raises the question on which this dissertation is intended to throw light: *how far has the discourse of urban sustainability, promoted at the Rio 'Earth Summit' of 1992 and at subsequent international fora, penetrated the world's national airport noise and urban planning policy systems, and subsequently the South African situation?* What has the scope of the discourse on urban airport noise planning revealed? The answer is it depends on the area of the world, and the commitment displayed by the role players. Those communities who are most affected by noise tend to be most vociferous and wealthy communities may complain even if the noise levels are relatively low. Poor communities may not complain because they are occupied with other more pressing concerns, or because their proximity to the airport supports their economic endeavours and if they were to move, they would face more economic hardship.

The term airport noise can be understood in different ways. For example, residents, aircraft operators, airports, planners all have their perspective. Cohen (2001) discusses features of the urbanisation experience that fragment, divide and polarise metropolitan areas. He does not mention airport noise, but it may be regarded as one such divisive force. If municipal leaders can communicate that the diverse members of the aviation community and surrounding residential community have a shared future, then there are possibilities for shared interests. If not, then the tendencies for polarisation and conflict over noise will continue to grow.

7.1.1 Summary of results

The results of the research are presented according to the problems which also guide the progression of the chapters.

The literature study and survey results in Chapters 2, 4 & 5 show that airport noise creates annoyance and interferes with activities of people who live in the vicinity of flight paths used by aircraft arriving at or departing from ORTIA. Two approaches to dealing with these problems which are of interest to human geographers are to make use of comprehensive land-use planning to keep noise sensitive land-uses away from airports and adapt aircraft flight tracks to avoid overflying noise sensitive areas. The conceptualisation of these approaches reveals that they have many aspects in common when dealing with aircraft noise around the world, such as modelling, measuring and monitoring aircraft noise, then using the results to reduce the total population affected by noise, to prevent noise ghettos from developing by improved planning.

In Chapters 4 and 5, the results of the survey which investigates annoyance at and interference with household tasks by aircraft noise were presented. From the analysis two findings are made. Firstly, it was found that night time aircraft noise is a problem around ORTIA. Secondly, it was found that people who live outside of the noise contours (calculated according to national standards) still report being annoyed by aircraft noise and that some of their household activities are interfered with. Chapter 5 investigates a different type of aircraft noise metric produced from the same data using another aircraft noise modelling program, the number of events, and associates the results with the survey responses. This information differs from an average in that the number of events above specified levels were examined. The intensity of the annoyance was found to increase with increasing noise level, and even more so with increasing frequency of flights. This addresses the third problem.

In answering the first two problems set out in the study, the primary aim has been achieved. The importance and relevance of aircraft noise calculation models in airport noise studies has been established. In Chapter 5, survey results are interpreted according to supplemental aircraft noise modelling techniques, and the usefulness of supplemental aircraft noise information is recognized. A modelling process incorporating night-time average energy airport noise modelling, and number of events is recommended for distribution to residents.

Observation of the planning processes in the vicinity of airports enables the researcher to determine to what extent the principles deduced from the literature study were applied. The result of this process is that the principles postulated for planning for airport noise could be assessed on whether or not, and how, they can be applied in practice and what the results are. The results are given in the following paragraphs, leading to the reassessment of the SANS standards to produce recommendations for effective land-use planning and optimisation of flight tracks in the vicinity of airports (see section 7.3.2).

One of the first consequences of not involving the surrounding community in the discovery stage of the selection / design of runways and flight tracks is that the broad acceptance of the flight tracks at a later stage in the planning phase is affected. The lack of involvement and continuity from one stage to the next could result in continual and confusing changes having to be made to flight tracks. Flight track parameters that emerged from aircraft departing from ORTIA at night are that residents who live some distance to the north of the airport, and outside the L_{Rdn} planning contours were bothered by noise from long-haul aircraft departing for Europe. Collaborative planning which includes the use of supplemental noise information in the form of the number of events occurring allows residents to understand the requirements of airport master planning with the necessity that all parties, in this instance, including the air traffic control authorities and the airlines be willing to reach a compromise.

It also transpires from this research that there is no evaluation scale for supplemental aircraft noise information readily in place. There is a good reason for this in that people's response to noise is very subjective and even varies in the same person depending on time of day and type of noise. However by interpretation of the results, it can be seen that as the number of events increases above 20, then even the lower levels become annoying for a large percentage of people (see Figure 5.14). This indicates a real problem. If the parameter strives not to be subjective, it will have to involve all the agents, including residents, air traffic controllers, pilots, aircraft operators and town planners in establishing it. The lack of such an evaluation scale can initiate new research opportunities. For example, number of events contours can be calculated at regular, predetermined intervals - for instance every five years. The number of events and the L_{Amax} of these events can be compared between time periods and the effectiveness of noise abatement and mitigation measures assessed.

This study reveals that the flight track planning process and what happens in the land use planning process must be carried over to future planning phases. The lack of agent involvement and long term planning foresight in the early planning phase can result in flight tracks being modified later in a manner which is inappropriate to the land use planning. Different agents participating in the flight track planning process have different concepts of the flight track planning and of noise dispersion. These differences need to be addressed by specialist experts. Remarks by the community such as that aircraft fly too low, there are too many aircraft, and can't they fly somewhere else have been common at ORTIA's AEC. Aircraft operators would like their aircraft to fly as directly as possible between airports to reduce fuel and maintenance costs. Noise from their aircraft is of less interest to them. The efforts of town planners who are on a long-term planning horizon, possibly of 50 years or more, are thwarted when air traffic controllers change their routes so that noise affects areas which had an expectation of reasonable quiet have these expectations dashed.

Community involvement is crucial to the success of land-use planning around airports. Community participation ensures that relevant issues will be looked at and that the community will identify with these issues, thus enhancing participation. Use of number of noise events above specified threshold values descriptors will make understanding aircraft noise more accessible to the community. Maximising the early and long-term participation of local people helps to determine the kind of land-use and flight track planning that should occur, or at least informs communities and planners why certain decisions to facilitate safe and efficient operation of aircraft are necessary.

The analysis of the needs of the economy, community and aviation as stakeholders is an integral principle to the framework. An understanding of the strengths and weaknesses of airport noise models will assist with realistic needs being articulated and met.

ORTIA is important to Ekurhuleni's economy and for job creation, but – little of its impact and what will be done to minimise this is covered in the IDP or the SDF. Until the community starts to register its response, one wonders what will be done.

7.1.2 Noise control in developing communities

South Africa is a diverse country with communities that may be regarded as developed (for example, those living in the suburbs) and those who are regarded as developing (for example those living in townships). While the noise control measures and criteria commonly in use are based on the experience of the developed world, the needs of the developing sector (in this study characterised by the residents of Tembisa) should not be ignored (Johnston 1992). In the late 1980s Johnston (1992), concluded that a community will remain relatively insensitive to noise as long as more basic needs such as food, shelter, security and employment are not met. Johnston believes that in this case, time and money should not be spent on remedial actions against noise in developing communities. Financial resources should be applied to meeting basic needs. However, the present study would suggest otherwise. Although the survey responses from the developing community in Tembisa may have been exaggerated due to the survey delivery mechanism, the results (of annoyance and interference with household tasks) should be taken into consideration. It is not suggested that any form of compensation be considered. Rather, resources should go into suitable planning, to serve the basic needs.

If the goals of the South African government, that the basic needs for housing, water, sanitation, food, employment and security will be satisfied, and it can be assumed that they eventually will be, at that stage a more vigorous response to noise can be expected (Johnston 1992). Those communities which currently are considered to be developing, and which are now affected by aircraft noise, may not be willing to tolerate excessive noise in the future.

Local authorities have no control over airport developments. Runways which are lengthened, realigned or even newly constructed will have flight routes designed for their use. The local authorities have no control over these flight routes, but should be provided with the opportunity to comment on them so that other options can be considered and unsuitable ones ruled out.

7.2 ALIGNING THE PLANNING HORIZONS OF THE TIME SCALES OF AIR TRAFFIC FLIGHT ROUTE PLANNING AND TOWN AND REGIONAL PLANNING

Average energy noise contours and supplemental noise information can be used by town planners and air traffic control authorities alike to better understand the impacts of their planning. Air traffic flight route planning and town and regional planning need coordination so that their time scales and planning horizons are aligned and system wide conflict is minimised (Rachami 2006). Planning for aircraft noise cannot be retrospective. Once there are houses under flight paths near an airport, noise mitigation measures need to be considered. Alternatively, if airspace is redesigned then aircraft may be routed over houses which they did not fly over before which those residents would find unacceptable. Using aircraft noise models to assess the impacts of these changes before they are implemented can assist with finding the best solution.

It has been shown in Chapters 4 & 5 that taking the impact of aircraft noise into account in land-use planning in the vicinity of airports is important. The survey has shown that aircraft noise is a stress factor which reduces the amenity people get out of their places of residence. Similarly, annoyance and interference with household activities from aircraft noise is experienced outside of the noise zones, and that even within the noise zones as established by the SANS standards, annoyance from noise and interference from noise is a factor to be considered by town planners. Aircraft noise models and noise descriptors other than average energy metrics can add to the understanding people have of noise in the vicinity of the airport.

ORTIA is unique in its constraints. Every planner and developer encounters different variables and conditions in space and time, and the reality is interpreted through conceptual systems and filters as it is transformed into perception. Planners can use information from aircraft noise models when laying out new land in the vicinity of existing airports, or when new developments at airports are planned. Airports which were in remote areas often attract new developments. People who work there want to live close to work. People who travel often want to live close to the airport.

The planning framework as proposed is aimed at alleviating past mistakes, preventing present mistakes from spreading and reducing future errors to the minimum. It is also an attempt to bring together acoustic experts responsible for calculating noise contours, town planners, residents and the aviation industry because though they come from different backgrounds with different expertise and have their own goals, they need to be brought together for planning purposes.

7.3 RECOMMENDATIONS

ORTIA is at the forefront of the sub-Saharan air network maintaining a position of significance and centrality as a transport node to the movement of humans. However, ORTIA itself also has a social space function (after McNeill 2004) where people go to greet and fetch, or drop-off and say goodbye to travellers, or simply to identify with aviation. Take for example the Airbus A380's visit to ORTIA in November 2006. Hundreds of people turned up just to see this huge new aircraft whilst the airport attracts visitors like no other mode of transport just to look at aeroplanes. The points raised in the first chapter about the necessity for aircraft noise planning are raised in the section below with regard to recommendations for an aircraft noise environmental agenda for cities.

7.3.1 Recommendations for a planning framework

Four planning framework recommendations (after Abbott & Pivo 2000) are made for improving the effectiveness of SANS standards as planning tools within a planning framework, namely:

- The presence of a strong comprehensive plan is a leading variable associated with the effectiveness of planning. This plan would involve the cooperation of the airport owners as well as the municipal authorities. Ekurhuleni Metropolitan Municipality's IDP is a start but is inadequate in its dealings with the aircraft noise impact at Ekurhuleni.

- Improve documentation of tools used and effectiveness, and promote the sharing of information. The limitations of L_{Rdn} should not be concealed – rather the usefulness of supplemental noise information should be underscored.
- Improve the use of seldom used but highly effective tools. For example TNIP and supplemental aircraft noise information in the form of number of occurrences of events can be taken into wider use. The helpfulness of frequently used but less effective tools can also be improved.
- Continue to develop new tools. The number of events above a specified threshold noise descriptor is a good example of the implementation of this recommendation. This is largely up to organisations (such as the FAA) with scientific and research responsibilities to update the software.

The first three bulleted points of the framework mentioned above are the most readily implementable since they involve considered application of readily available techniques and software. This is not to ignore the fourth. Users of the software and framework have a responsibility to provide feedback (as done by the writer) to scientific and research organisations to help them design more suitable tools.

7.3.2 Aircraft noise problems: political solutions

Referring to aircraft noise as a pressing environmental problem can be misleading since it does not involve shortage of some resource, e.g. land or water, or obvious visible pollution, e.g. air pollution. Rarely does the noise from aircraft threaten hearing. Because of this, the aircraft noise problem is not regarded politically as a matter for urgent attention. The many households living in areas affected by aircraft noise choose such sites possibly out of ignorance, but also because town planning and aviation authorities fail to plan for urban growth and air traffic growth or to allocate suitable sites for residential development, or flight routes.

There are shortages of suitable land in Ekurhuleni, but even here authorities should do much more to support the search for and provision of suitable land where aircraft noise model contours are an essential tool in the allocation of land. Hardoy, Mitlin & Satterthwaite (2001) are of the opinion that a failure of government can be said to underlie environmental problems. This belief can be transferred to the problems of residential areas being planned too close to airports, and air traffic movements being allowed to grow to the extent that aircraft noise contours intrude on residential areas which were previously not in affected zones. Residents are not protected and local authorities need to plan in advance to ensure that sufficient land is available. Aircraft noise contours based on predicted air traffic growth over defined periods, perhaps up to 50 years, need to be used by authorities to guide their decision-making. The problem with these predictions is that the further into the future they are, the less accurate they are likely to be due to the changes in the multiple variables needed to perform the prediction calculations. The resultant predictions are used to derive the contours which will also be less accurate the further into the future the contours represent.

The concept above is not meant to imply that government agencies should be responsible for all the planning tasks. Their role should also be to provide the framework within which the aviation industry can operate, or take measures to ensure public accountability by the aviation industry for their noise emissions. The long delayed South African aircraft noise and engine emissions policy would go a long way to guiding the aviation industry and preventing failures in planning leading to land-use incompatibility in the future.

Growing pressure for action on aircraft noise environmental problems in developed countries must continue in all urban areas. Most of the literature on aircraft noise environment problems centres on a handful of airports in the largest cities, typically Frankfurt, London Heathrow, Los Angeles, New York, San Francisco, Sydney and Zurich. Yet only a small percentage of the population lives in large cities. A large proportion of people affected by aircraft noise live in smaller urban areas, and some of these are in developing countries where plans to phase out and ban noisy aircraft are a long way off.

Building on the basis for aircraft noise environmental management through the use of noise contours should focus on the aspect which follows in Section 7.3.3.

7.3.3 Incorporating an airport noise planning framework into Ekurhuleni's IDP

The proposed collaborative airport noise planning framework in Section 7.3.1 should contribute to the multipurpose planning of urban areas in such a way that it will add to the protection of residents living under flight paths and not lead to restrictions on sustainable economic benefits and growth for the country. The airport noise planning framework combines into one framework the environmental and urban dimensions of human geography.

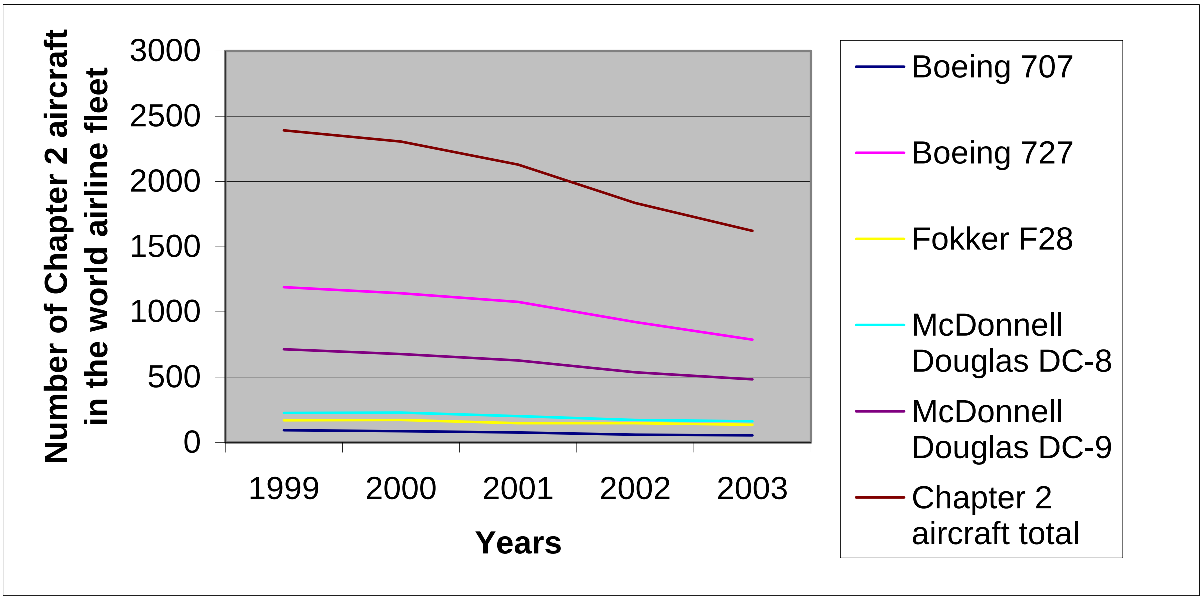
The IDP is a constantly evolving document that will be continually developed, refined and improved. Annual IDP reviews will address new challenges that arise from its implementation, as well as the changing needs and aspirations of Ekurhuleni's communities. "The IDP will always be responsive to the external environment, ensuring that the Ekurhuleni Metropolitan Municipality is flexible enough to address all future challenges. Our aim, in fact, is to develop our IDP to such an extent that it becomes proactive rather than reactive". (Ekurhuleni 2003a: 48).

In searching for ways to describe aircraft noise, supplemental aircraft noise information can be extended into two strategies. One is to concentrate noise in small areas. This would require an acknowledgement that annoyance and disturbance in these areas would be high and that the resultant concerns of residents be effectively dealt with. The other is to use noise load sharing where aircraft fly on tracks, which over a period of time would result in reasonably equally shared noise exposure. The choices so made will depend on the land use patterns around individual airports. For example, if an even population density is present, noise load sharing may be better. If the land use pattern is uneven, then N60, N70 and N80 contours can be used to focus the noise where it least affects people by modifying flight tracks accordingly. These number of events contours have proved to be a more popular information type. Planners and other administrative officials have to recognise that technical, scientific average energy noise information is regarded as less important by people. These officials should provide accessible information from early on to influence and guide the land development process.

Another way of interpreting the survey results is that "quiet" is valued by the population. Noise exposed areas ought to be protected against urban expansion by planning and development practice against consumption for urban expansion so that planning targets can be realised and embedded in general planning ideas and that some "quiet" can be experienced. The government white paper (South Africa 2005) provides an opportunity for land use planning, but quality targets must be set and used as strategic tools. For example the reduction of the size of the N70 noise contour could be a goal achieved so that the population exposed is also reduced over time. To do this, the white paper should explicitly address the issue of supplemental aircraft noise information.

7.3.4 Aircraft noise reduction technology at source

Between 1999 and 2003 the worldwide Chapter 2 aircraft fleet reduced in size from about 2400 aircraft to about 1600 (Figure 7.1).



Source: Aerospace Industries Association (2006)

Figure 7.1: The decline in numbers of noisy aircraft

This represents a significant reduction in noise simply through removal of noisy aircraft. But what other potential does noise reduction technology have? The Quiet Technology Programs have resulted in the incorporation of such noise-reduction technologies as nozzle chevrons, spliceless inlet linings, extended lining locations, and redesigned wing anti-icing system on existing and future airplanes (Herkes 2006). No doubt these will have their place, but given current technology and knowledge no radically quieter aircraft are envisaged for the near future. Since town and regional planning are best based on present knowledge a conservative approach to town planning should be adopted until such time as it is evident that substantially quieter aircraft are in the offing.

7.3.5 More effective tools and metrics

In their report to the United States Congress, Waitz et al (2004) recommend that more effective metrics and tools, including supplemental metrics to assess and communicate aviation's environmental effects, should be developed. The relevance of this recommendation to South Africa is clear. The United States has the busiest airline traffic in the world – in the first six months of 2006, nine out of ten of the worlds busiest airports as measured according to aircraft movements were in the United States (Airports Council International 2006) – and has an average energy airport noise policy (FAR Part 150) in place. Waitz et al's (2004) recommendation is made in the light of dissatisfaction with average energy metrics and the need to provide better information to airport neighbours. If this has been recognised in the United States where average energy noise contours have been a requirement for some time and where the provision of supplemental aircraft noise information is now being encouraged, then in South Africa supplemental noise information can be applied to the problem, and make a difference in understanding and dealing with the problem, a lot sooner.

7.4 PESSIMISTIC REALITIES

It is easy to find pessimism in a context of discussions on aircraft noise impact on surrounding neighbourhoods. Aircraft noise does not directly cause serious health problems, like poor air quality can; rather the effects are measured in terms of annoyance and interference with activities, resulting in a negative impact on quality of urban life. In South Africa airlines are not prohibited from adding noisy aircraft to their fleets nor is there a planned phase-out of noisy aircraft in place, meaning that these aircraft can be expected to operate into the foreseeable future.

Curfews on aircraft operations at times when people are likely to be most sensitive are also not implemented and neither are financial restrictions. Economists have developed principles and techniques for the total economic valuation of environmental and related investment. Total economic valuation measures both the direct and indirect effects of investment in environmental, social and economic assets. This includes non-market valuation aircraft noise. Aircraft noise at night when it is very disturbing could be regarded as more expensive than similar movements during the day when people are less likely to be disturbed. These movements may be priced accordingly, either to discourage night operations with noisy aircraft, and to raise funds to pay some form of compensation to affected residents.

Whilst there remains a perception that aircraft noise is not a health problem, lawmakers are not inclined to make it a priority. The motivation to make a difference is deficient and the noise issue is likely to become a more serious problem as aircraft flights increase and the demand for urban space continues.

7.5 FUTURE FRAMEWORK DIRECTION: A PROGRAMME FOR ACTION AND NEGOTIATION

The difficulties encountered in scaling up actions for aviation-noise sustainability and increasing the effectiveness of their impact are threefold. The first lies in conflicting views on how to implement average energy noise contours given the rapid pace of urbanisation and growth in air travel. The views of the SABS, local municipal authorities and airport neighbours play a leading role in the conflict. The SABS have issued standards which in their view are sufficient. Local authorities recognise the technical authority of the SABS but don’t have the teeth in the form of bylaws to enforce the standards, and airport neighbours don’t trust the noise contours, believing that they under report noise and are misleading.

The second difficulty relates to the political processes required to translate principles of aircraft noise management into meaningful practice. The CAA have a draft white paper on aviation and the environment which is yet to be finalised and implemented by the Department of Transport. Lastly are the structural obstacles that are found at different levels of the policy and decision making process.

Three decades after the SABS first issued the standards, there are growing misgivings on the most effective course of action to take. The question remains to what extent have the standards been translated into courses of action by local authorities and what future potential will the CAA's white paper policy realise to make aviation more sustainable? Despite the usefulness of supplemental aircraft noise ideas documented here, the role of the aviation industry, town planners and airport neighbours in South Africa in sustainable development is under-represented. Aviation is increasingly recognised as part of the noise problem and rarely as part of the solution and a blinkered approach is frequently encountered in planning in the vicinity of airports as evidenced by the quantity of inappropriate housing developments near airport flight paths. A major reason for this lack of uptake is the poor understanding of planning for noise.

This dissertation argues that one answer to dealing with aircraft noise requires an in-depth understanding of the noise problem at a different level so as to empower people to devise strategies that have a positive impact. Implementing supplemental aircraft noise based collaborative planning will empower citizens' participation through this democratisation of knowledge.

To progress airport-noise sustainability, action should be taken on three complementary paths to advance the process of consolidating action for aviation-noise sustainability. These are:

- Updating SABS standards to encourage provision of additional supplemental noise information
- Completing the CAA white paper on aviation and the environment and implementing it as policy, including reference to supplemental noise analysis

- Harmonising the planning horizons of town planners and air traffic controllers, then using supplemental noise analysis to expose the consequences of town planning and airspace design proposals.

The limited trust in and reliability of the SABS standards to guide land use planning around airports contribute to a lack of motivation to even bother with using them. Supplemental aircraft noise information and particularly the number of event occurrences, provided in a format which is readily understood by the layperson will play an important role in public involvement and decision making processes.

7.6 AIRPORT NOISE AND ENVIRONMENTALLY SUSTAINABLE URBAN DEVELOPMENT: CONCLUDING REMARKS

An assessment of outcomes of SANS 10103 and SANS 10117 is difficult to make for at least four reasons.

- Firstly, the scope is broad. Land-use planning is based on a 24 - hour period. Noise-sensitive night periods are only catered for from 22:00 to 06:00. The 18:00 to 22:00 time period when people are at home and when the survey in this study has revealed that household activities are disrupted is not incorporated. The number of events is not included. It is impossible to see whether the balance between success on one front is outweighed by failures in other areas.
- Secondly, three years since the inception of these standards is too short for making a conclusive assessment of the standards.
- Thirdly, there is no simple yardstick of measurement. Land-use planning is on a long timeframe which cannot be evaluated in a few short years.
- In the final instance, there is the problem of considering what would have been the case if the standards had never been implemented.

A few general conclusions can still be drawn with these reservations in mind. Firstly, SANS 10103 and 10107 represent a moral commitment which provides a yardstick for critique although efficient action will only materialise slowly. Secondly, to implement the standards, local authorities will have to build capacity and develop their potential to become vehicles for development towards social justice and economic development. Thirdly, although the standards are implemented as a top-down project, participation by local authorities and other stakeholders is encouraged. Fourthly, the standards embody a positive strategy for modernisation which tackles the polarised approaches of 'business as usual' and the 'fundamentalisms' of opponents to airport development. Because these standards are already in place, an addendum to the standards requiring the provision of supplemental noise information, particularly in the form of number of event occurrences would go a long way towards strengthening the moral commitment of SANS, implementing the standards, improving local authority participation and embodying a positive strategy for modernisation.

A number of items can also be listed on the negative side. The relationship between scientific intent and real actions taken thus far is tenuous. Money to implement the standards must be made available. Town planners, business and industry are slow to change their behaviour in an acoustically environmentally friendly direction. Issues which are crucial for acoustically sustainable urban environments, such as aircraft noise, are not given priority. For example, reducing aircraft emissions will have a negative impact on noise as more fuel has to be carried (Waitz 2006). Technological advances bring some solutions to the noise problem: the trick is to avoid some of the problems which technology seems to bring with it (Haughton & Hunter 1994). Thus it is not surprising that Sandford Fidell in his assessment of the effectiveness of aircraft noise regulation writes that "… limitation of noise levels to certain values of favoured noise metrics may therefore provide the appearance, rather than the substance, of a solution to problems of community reaction to aircraft noise" (Fidell 1999: 17).

Although the overall assessment of the national standards has a negative flavour, there are positive examples in a national context. At the larger airports in South Africa, and slightly farther afield in Botswana, at least seven major airports are involved in noise and land-use master planning studies. Some attention is being given to participation and consensus building, which will continue to grow. Sustainable development is "… at once economic, social, political and environmental. It is not limited to what rates of economic growth are environmentally tolerable. Rather, it is more about patterns of development and their environment, social and economic impacts." (Pugh 2000: 206).

The measures at the disposal of the interested community can be summarised as a mixture of international agreements, government policies in waiting, efficient use of private resources and initiatives by grassroots organisations and local governments. More simply, the community needs to think and act, globally and locally. Notwithstanding the best efforts, not everyone will be satisfied, but with those in authority being seen to be making the best effort, more will.

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APPENDICES

Appendix A: Examples of the English and Afrikaans versions of the covering letter, questionnaire, and reminder letter

Appendix B: Tables upon which graphs are based, and Chi squared tests of significance.

In this appendix, the tables of data from which the graphs were drawn are included, and where relevant, the chi squared significance test results. The pattern will be followed of presenting first the figure number and title of the figure, then the table, then the chi squared significance test.

Table B 1: Figure 4.4 Number of surveys distributed and returned:

Group	Distributed	Returned
Control	50	31
Suburb	750	232
Township	80	66
Total	880	329

Table B 2: Figure 4.5 Percentage of responses returned per sub group, and the total percentage returned:

Group	% returned
Control	62
Suburb	30.93
Township	82.5
Total	37.38

Table B 3: Figure 4.6 Control group and experiment group percentages reporting being highly annoyed due to aircraft noise between 6pm and 6am:

Group	% highly annoyed
Control	3.23
Experiment	32.77

Number of respondents: 316

Table B 4: Figure 4.7 Annoyance reported vs. frequency of hearing aircraft noise.

	Highly Annoyed	Considerably Annoyed	Moderately Annoyed	Slightly Annoyed	Not Annoyed
Never hear	0	0	14.29	14.29	71.43
Seldom hear	0	0	0	8.7	91.3
Sometimes hear	0	0	13.89	22.22	63.89
Often hear	1.49	16.42	28.36	32.84	20.9
Very often hear	58.64	20.37	11.11	6.79	3.09

Number of respondents: 327

Chi squared: 137.30

Table B 5: Figure 4.8 Percentage of control group and experiment group split into suburb and township groups reporting being highly annoyed due to aircraft noise between 6pm and 6am

Group	% highly annoyed
Control	3.23
Suburb	30
Township	42.42

Number of respondents: 327

Table B 6: Figure 4.10 100% bar graph illustrating the distribution within each sub-group including control group, and experiment group split into suburb and township groups reporting being highly annoyed due to aircraft noise between 6pm and 6am

Group	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not at all annoyed
Control	3.23	3.23	3.23	6.45	83.87
Suburb	30	14.78	13.04	14.35	27.83
Township	42.42	15.15	19.7	16.67	6.06

Number of respondents:

Control: 31

Suburb: 230

Township: 66

Chi-squared: 39.73

Table B 7: Figure 4.13 Percentage Sleep, TV, Phone and Work, very often interfered with, by sub-group.

Group	Sleep	TV	Phone	Work/study
Control	6.45	0	0	0
Suburb	22.84	34.4	27.06	18.69
Township	36.36	44.62	53.85	25.81

Number of respondents : Sleep 329, TV 311, Phone 311, Work/study 288.

Chi squared: Sleep 38.24, TV 65.25, Phone 66.77, Work/study 25.33.

Table B 8: Figure 4.16 Percentage of residents who would consider moving vs. how often aircraft noise is heard.

How often aircraft noise is heard	Would consider moving	Would not consider moving
Never	0	100
Seldom	8.7	91.3
Sometimes	0	100
Often	14.71	85.29
Very often	55.41	44.59

Number of respondents: 319

Chi-squared: 49.07

Table B 9: Figure 4.17 Percentage of township respondents reporting being highly annoyed by L_{Rdn} noise zone.

L_{Rdn} noise zone	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not annoyed
<55	42.19	15.63	20.31	17.19	4.69
55-60	1	0	0	0	1

Number of respondents: 66.

Table B 10: Figure 4.18 Percentage of suburb respondents reporting being highly annoyed by L_{Rdn} noise zone:

L_{Rdn} noise zone	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not annoyed
<55	9.84	4.92	13.11	6.56	65.57
55-60	14.75	14.75	13.11	31.15	26.23
61-65	46.15	20	7.69	13.85	12.31
66-70	40	28	28	4	0
70-75	77.78	11.11	11.11	0	0

Number of respondents: 230

Chi-squared: 71.84

Table B 11: Figure 5.2 Reported annoyance of the suburb group by 12 hour L_{Aeq} noise zone

L_{Aeq} noise zone	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not annoyed
<55	11.02	10.17	12.71	19.49	46.61
55-60	48.44	17.19	9.38	14.06	10.94
61-65	33.33	33.33	19.05	4.76	9.52
>66	65.38	15.38	19.23	0	0

Number of respondents: 230

Chi-squared: 68.87

Table B 12: Figure 5.4 Comparison between suburb group response when classified according to 12 hour L_{Aeq} noise contour and 24 hour L_{Rdn} contour.

Average energy noise zone	Highly annoyed	Considerably annoyed	Moderately annoyed	Slightly annoyed	Not annoyed	
LRDN <55	9.84	4.92	13.11	6.56	65.57	100
L_{Aeq} <55	11.02	10.17	12.71	19.49	46.61	100
LRDN 55-60	14.75	14.75	13.11	31.15	26.23	99.99
L_{Aeq} 55-60	48.44	17.19	9.38	14.06	10.94	100.01
LRDN 61-65	46.15	20	7.69	13.85	12.31	100
L_{Aeq} 61-65	33.33	33.33	19.05	4.76	9.52	99.99
LRDN 66-70	40	28	28	4	0	100
L_{Aeq} 66-70	65.38	15.38	19.23	0	0	99.99
LRDN 70-75	77.78	11.11	11.11	0	0	100
L_{Aeq} 70-75	100	0	0	0	0	100

Number of respondents: 230

Table B 13: Figure 5.5 Suburb group. Sleep disturbance 12 hour night L_{Aeq}

L_{Aeq} noise zone	Never	Seldom	Sometimes	Often	Very often	Often/very often
<55	40.54	18.92	18.02	9.91	12.61	22.52
55-60	11.29	9.68	12.9	30.65	35.48	66.13
61-65	9.52	4.76	33.33	28.57	23.81	52.38
>66	0	4.17	29.17	16.67	50	66.67

Number of respondents: 219

Chi-squared 53.30, $P<.0001$

Table B 14: Figure 5.6 Suburb group. Phone disturbance 12 hour night L_{Aeq}

L_{Aeq} noise zone	Never	Seldom	Sometimes	Often	Very often	Often/very often
<55	36.04	18.02	18.02	18.92	9.01	27.93
55-60	6.56	13.11	16.39	27.87	36.07	63.94
61-65	4.76	0	14.29	23.81	57.14	80.95
>66	4.17	0	8.33	25	62.5	87.5

Number of respondents: 218

Chi-squared: 51.24

Table B 15: Figure 5.7 Suburb group. TV disturbance 12 hour night L_{Aeq}

L_{Aeq} noise zone	Never	Seldom	Sometimes	Often	Very often	Often/very often
<55	29.2	15.93	20.35	21.24	13.27	34.51
55-60	6.78	5.08	11.86	25.42	50.85	76.27
61-65	4.76	0	9.52	19.05	66.67	85.72
>66	8	0	4	24	64	88

Number of respondents: 218

Chi-squared: 51.06

Table B 16: Figure 5.8 Suburb group. Work / study disturbance 12 hour night L_{Aeq}

L_{Aeq} noise zone	Never	Seldom	Sometimes	Often	Very often	Often/very often
<55	44.76	22.86	12.38	14.92	5.71	20.63
55-60	23.53	11.76	15.69	23.53	25.49	49.02
61-65	10.53	15.79	10.53	26.32	36.84	63.16
>66	9.09	4.55	18.18	18.18	50	68.18

Number of respondents: 198

Chi-squared: 35.27

Table B 17: Figure 5.14 12 hour N60, N70, N80 suburb group reporting being considerably annoyed and highly annoyed.

Number of events	N60	N70	N80
<10	22.64	19.8	28.83
10-20	13.95	29.41	68.42
21-50	57.28	70.83	89.74
>50	83.87	95.65	88.89

Number of respondents: 228

Chi-squared N60: 76.88

Chi-squared N70: 89.82

Chi-squared N80: 71.79

Table B 18: Figure 5.15 12 hour N60, N70, N80 Sleep reported as being often and very often disturbed

Number of events	N60	N70	N80
<10	19.61	20.21	29.87
10-20	15.38	33.33	57.9
21-50	52.52	60.87	75.68
>50	83.33	91.3	88.89

Number of respondents: 219

Chi-squared N60: 61.38

Chi-squared N70: 66.78

Chi-squared N80: 49.76

Table B 19: Figure 5.16 12 hour N60, N70, N80 TV viewing reported as being often and very often disturbed

Number of events	N60 Suburb	N70 suburb	N80 suburb
<10	37.26	34.38	41.83
10-20	20	38.71	94.74
21-50	71.14	83.82	89.19
>50	93.33	95.65	100

Number of respondents: 218

Chi-squared N60: 66.60

Chi-squared N70: 62.95

Chi-squared N80: 48.08

Table B 20: Figure 5.17 12 hour N60, N70, N80 Telephone conversations reported as being often and very often disturbed

Number of events	N60 Suburb	N70 suburb	N80 suburb
<10	26	24.47	33.33
10-20	12.82	38.71	89.47
21-50	65.65	74.28	86.49
>50	83.33	91.3	88.89

Number of respondents: 218

Chi-squared N60: 70.30

Chi-squared N70: 64.45

Chi-squared N80: 55.74

Table B 21: Figure 5.18 12 hour N60, N70, N80 Work or study reported as being very often disturbed

Number of events	N60 Suburb	N70 suburb	N80 suburb
<10	22.45	18.89	21.43
10-20	5.71	17.86	68.75
21-50	46.59	56.67	74.29
>50	73.07	85	85.71

Number of respondents: 198

Chi-squared N60: 45.15

Chi-squared N70: 50.17

Chi-squared N80: 53.55

Table B 22: Figure 5.19 12 hour N60, N70, N80: Would consider moving because of aircraft noise.

Number of events	N60	N70	N80
<10	16.67	13.73	16.46
10-20	13.33	14.71	57.89
21-50	42.72	55.56	76.92
>50	64.51	78.26	100

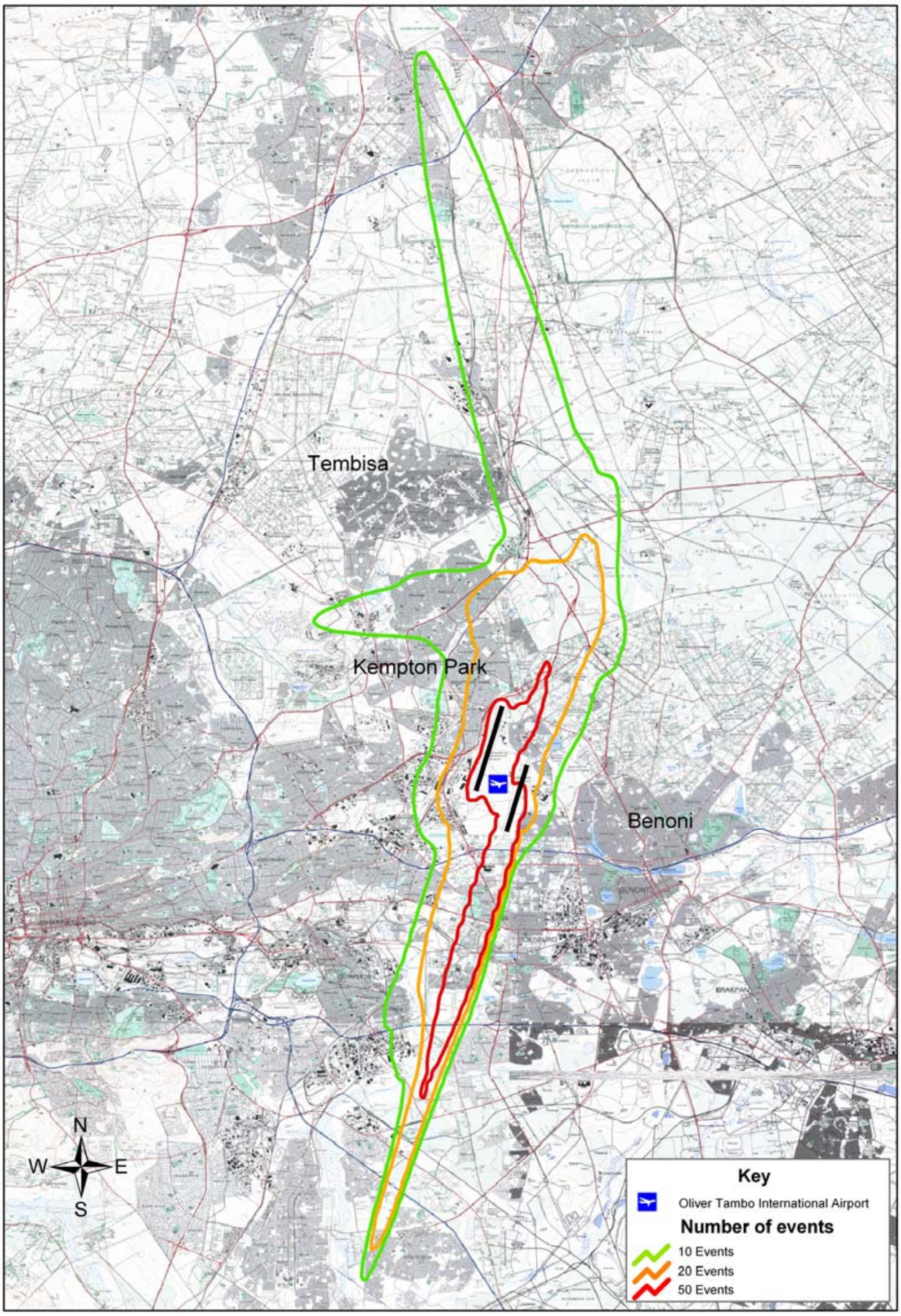
Number of respondents: 231

Chi-squared N60: 43.23

Chi-squared N70: 59.84

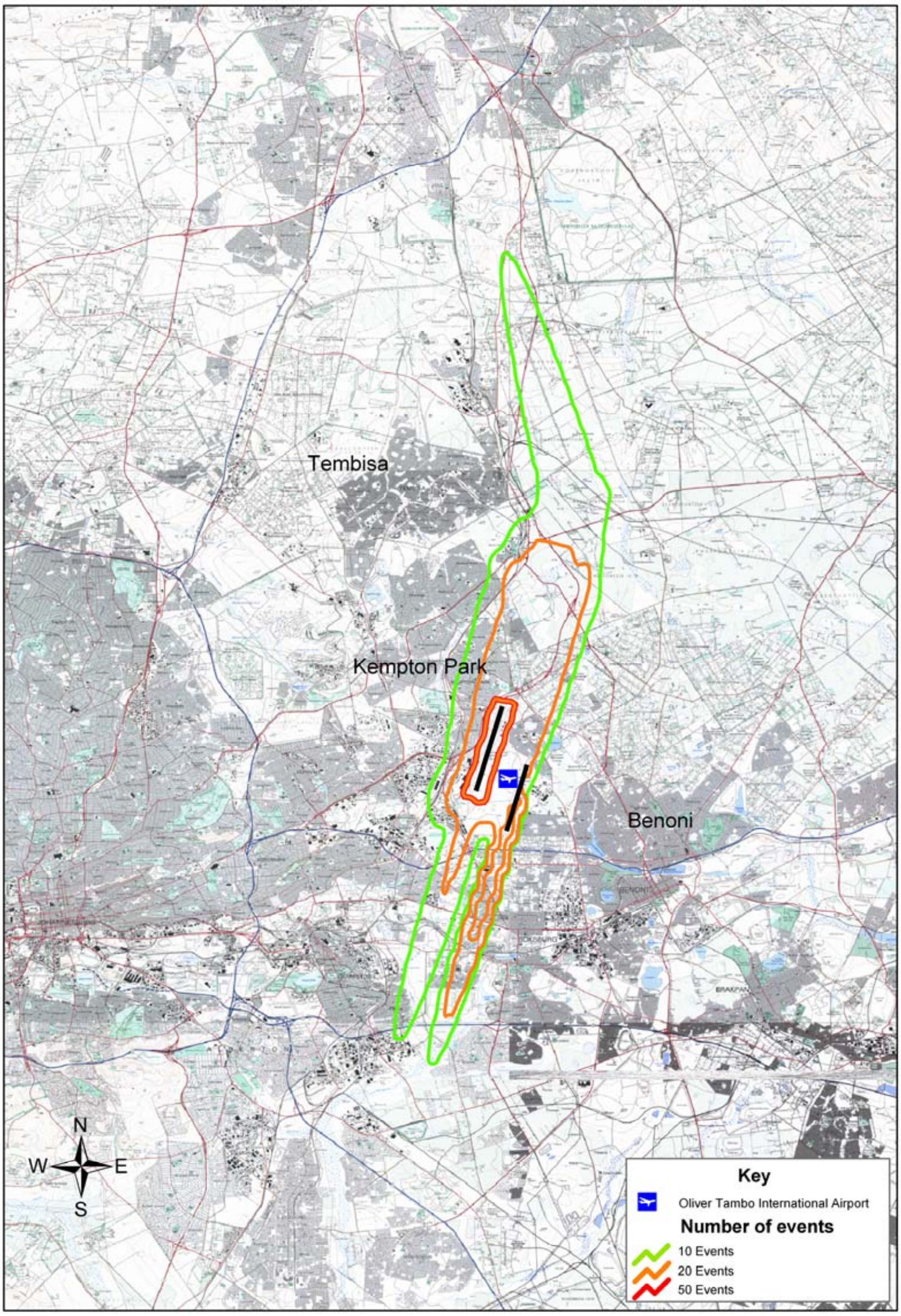
Chi-squared N80: 77.50

Appendix C: Full spatial extent of N60 and N70 contours



Source: Compiled by author

Figure C1: Full spatial extent of N60 contour.



Source: Compiled by author

Figure C2: Full spatial extent of N70 contour.