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A comparison of models measuring the implicit price effect of aircraft noise

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Abstract

This paper extends work from an earlier paper that involved measuring the effects of airport noise on the housing environs of Adelaide Airport in South Australia. The original study used multiple regression analysis in a log-linear form to estimate the implicit effect of aircraft noise using a series of dummy variables as a measure of aircraft noise in an hedonic function. This paper which uses GIS as a data management tool, extends this work by comparing models using different functional forms and also uses artificial neural networks as an alternative method to estimate the implicit price effects. It places the research within the context of other international studies as well as reviewing alternative methodologies for noise estimation used in the UK and the US.

Key words airport noise, hedonic pricing, environmental impact, regression modelling, artificial neural networks

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Introduction

In 1999 a proposed expansion of the international terminal at Adelaide Airport in South Australia (SA) resulted in the commissioning of a socio-economic study of the impact of current and projected new airport activity upon adjacent local council areas (Burns, Kupke and Rossini, 1999). This study included a consideration of demographic and employment patterns, volumes of commercial and industrial land sales as well as a review of local house price levels with respect to the Adelaide Statistical Division (ASD). While the impact of airport noise on residential values was not explicit within the review process it appeared from data presented within the study that price levels of properties affected by airport noise were more buoyant than those of properties across the wider ASD. Curiosity about this issue prompted a paper that explored whether and how the impact of airport noise and proximity on residential property values has changed over time (Burns et al, 2001). This paper relied upon two log-linear multiple regressions to estimate the percentage effect of aircraft disamenity through dummy variables that based on published ANEC measures. The paper found that the effect of significant aircraft noise (disamenity) would led to reductions in value of between 11.6% and 16.2% depending upon the level of noise and that this effect had changed over time. One of the suggestions from this paper was that the log-linear model may not be the best approach to estimate the effect of aircraft noise and that other functional forms were worthy of consideration.

This paper considers the use of a linear and log-linear function form of the regression model and also uses artificial neural networks to explore the possibility of further functional forms. Artificial neural networks (ANN) have been used since the 1990's as a means of modelling property prices in a manner analogous to hedonic price modelling using regression analysis. Initial work by Borst (1991) was followed up by major studies such as Evans et al (1993), Worzala et al (1995) and McCluskey et al (1996). Rossini (1997) found that the method was suitable for estimating residential property prices in Adelaide and could provide results that were consistent with regression analysis but with different structural forms.

Background

Adelaide, with a population of one million, is the state capital of South Australia and lies in a coastal plain between the Adelaide Hills to the east and Gulf St. Vincent to the west. The city centre is located some nine kilometres from the coast, approximately mid-way between the coast and the hills. Adelaide International Airport extends from some seven kilometres west of the city centre to the coast. Figure 1 in the appendix provides a map of metropolitan Adelaide that indicates the relative positioning of the coast, the airport, the city centre and the backdrop of the Adelaide Hills.

With a view to increasing the level of international air traffic through Adelaide, extensions to the two main runways were proposed by the then Federal Airports Authority and approved in 1997. Building work on the runway extensions was completed by the end of 1999. In the 2000 budget the Federal Government introduced an insulation program for Adelaide worth $63.7 million which, over 4 years, was to award grants to some 550 households and 4 public institutions thought most adversely affected by the increased air traffic noise. The Government aimed to recover these costs from a levy on jet aircraft landings. As the compensation amounted to up to $65,000 per individual dwelling there was intense local interest in the eligibility criteria. The Department of Transport and Regional Services determined that residential properties within the 30 ANEI contour qualified for compensation and issued a map indicating the eligible households. However as this map revealed, street, rather than strict noise boundaries determined compensation, and the outcomes were considered arbitrary and inequitable by a number of ineligible households. Local media, Local Government and the standing Federal Member of Parliament all expressed concern. This study reflects the price patterns of house sales in the year following these events and could offer some preliminary insights as to the basis of a sounder compensation outcome.

Literature Review

The literature review presented selects elements from the three strands that bear upon the analysis. First, there is the early economic analysis that recognised and explored the notion of 'quiet' as a luxury good. In this literature little attention is made to consider different degrees of noise. Second, attention is given to the measurement of noise, specifically noise associated with aircraft. Finally there is the empirical literature that has been concerned with attempting to place values (or costs) on measured noise levels.

Early Economic Considerations

In an early but important text based on participation in the Roskill Commission (1971) into a third London airport, Walters (1975) broadly discussed the theoretical basis for quantifying the impact of airport noise on residential property prices. He identified that typically the noise impact is concentrated under flight paths at either end of runways. Other dwellings roughly the same distance from the airport but not under the flight path may enjoy an environment virtually free of airport noise. Walters showed that it was possible to compare the rate of depreciation of homes in order to find the variation the market places on environmental quiet based on the supposition that for any given price of house there is a uniform depreciation for a given level of noise. He concluded that the income elasticity of the demand for quiet was between 1.7 and 2, which implies that as income increases people are willing on average to spend a larger fraction of their income on a quiet life.

Thus quietness can be considered a luxury good and given that the correlation between prices paid for property and permanent income is very high, this elasticity should be also reflected in prices paid by households for residential property. Under conditions of equilibrium the supply of quiet and noisy houses will equal demand. Any increase in the supply of noise will increase the number of noisy houses and reduce the number of quiet houses. This, therefore, should increase the price of quiet houses and reduce the price of noisy ones.

Other earlier analysis by Pearce (1978) and Nelson (1980) explored the connection between cumulative measures of airport noise and property price. The authors also devised the noise depreciation index (NDI) that captures the importance of cumulative rather than single event analysis. Here, again, no special attention was given to varying noise levels or to the wider range of noise characteristics that influence individuals' responses to noise.

The Measurement of Noise

Household exposure to aircraft noise is typically measured by one of a number of composite indices, in Australia by the Australian Noise Exposure Index (ANEI), the Australian Noise Exposure Forecast (ANEF) or the Australian Noise Exposure Concept (ANEC). These measures, which are very similar to those used in other countries, are defined in detail in the Adelaide Airport Master Plan (Adelaide Airport, 1999). Spatially, each of these measures of aircraft noise may be represented through contours that link points of equal noise exposure and are shown in a similar way to contours on a map representing height. The ANEF system is currently the most widely used and is based upon forecast traffic movements on an average day, taking into account the types of aircraft involved as well as likely runway movements and flight path patterns. The system is used to define acceptable development categories as well as the communities' likely response to aircraft noise. It relates householder's' subjective responses to aircraft noise to a scientific measure incorporating the influences of factors such as intensity, duration, frequency and temporal distribution of aircraft related sound. Typically ANEFs are categorised by noise contours of 20, 25, 30 and 40. Below the 20 ANEF level noise effects, in terms of the local community are deemed to be negligible. Within the 20 to 25 range noise begins to have a detrimental impact while above 25 ANEFs the effect becomes progressively more severe and would usually preclude new developments involving residential accommodation, schools, universities and hospitals. An Australian Standard (AS 2021) has been developed based on this system and provides local authorities with guidelines for planning land uses around airports.

The ANEF system yields a number of measures which are used for different purposes. One of these, the Australian Noise Exposure Concept (ANEC), which is based on indicative data on aircraft types, operations and flight zones, is another measure of aircraft noise. The ANEC system is basically a planning tool useful in scenario analysis, closely related to the ANEF system and one that generates almost identical noise contours in those cases where both measures have been derived. In this research use is made of the ANEC system as the contours associated with this measure are available for a greater number of time periods. Provided the predicted value that underlies the ANEC contours are in close agreement with events that actually transpire, these contours canbe used as interpolations between the less frequently derived ANEF measures.

Not all authors agree that a single composite noise index is appropriate and Levesque (1994) has argued that it is not the frequency of individual or intermittent noise that inflicts the most discomfort on local residents but the background level of continuous noise. Levesque argues that the Noise Exposure Forecast (NEF) methodology ignores the *a priori* restriction on regression analysis by combining loudness and frequency into one index. He instead represents noise conditions by disaggregation of this index into variables representing sound pressure levels, frequencies of over flights and the variability of the noise as factors influencing residential property prices.

Based upon the kind of approach suggested by Levesque, the standard unit of noise measurement used in the UK has become the “Leq”, a measure which allows for the disaggregation of noise exposure and includes measures of approach and departure routing, of traffic levels and aircraft types, as well as dispersion of individual flight tracks and average flight profiles (Pitt and Jones, 2000).

Empirical Evidence as to the Value of Measured Noise Levels.

Given a quantitative measure of noise levels the most common method of empirical analysis has been regression analysis. Typically this research has embodied the hedonic pricing approach as used in an early automobile industry study in Griliches (1961) and developed at greater length in Rosen (1974). This approach has been widely applied with regard to the impact of aircraft noise on residential property values (Pommerehne 1986, 1987; Burns et al 1989; Streeting 1990; Levesque 1994).

In this approach, samples of property transactions are drawn from neighbourhoods exposed to varying degrees of noise. Each transaction associated with a set of physical characteristics such as size, style, condition, date of sale and location features including exposure to aircraft noise. When closing prices of transactions are regressed on these characteristics the technique is called the Hedonic price estimation. The regression coefficient of the noise characteristics measures the economic impact of noise on the property market. Such Hedonic pricing affords the opportunity to quantify external costs, which can be internalised into the pricing structures at the source of the negative impacts. As Streeting has pointed out, some caution is required in that it is important to recognize that the noise evaluations obtained using this approach will vary in accordance with the quality of data, the functional form of the implicit price function and the statistical qualities of the equation.

In an early Bureau of Transport Economics study Abelson (1977) reported on a 1972 to 1973 study that quantified the effects of airport noise and traffic upon house prices for Sydney’s Kingsford Smith Airport. Abelson concluded that there was a significant relationship between house prices and aircraft noise in the NEF 25 area and above and that noise mattered more to high-income earners. He used the normal sample and Hedonic pricing approach with log of house price as a function of linear variables to suggest that on average house prices fell by .4 percent for a 1-unit change in the NEF index. This approach means that quiet has been measured as a given percentage of house prices for all levels of price.

An econometrically more sophisticated study of the impacts of aircraft noise on the Swiss city of Basle, involving a comparison of Contingent Valuation and Hedonic approaches, was undertaken by Pommerehne (1987). Using non-linear maximum likelihood estimation techniques he estimated that house prices were 6.6 percent lower in areas exposed to high levels of aircraft noise.

In further research using Australian data, Burns *et al* (1989) undertook for the Federal Airports Corporation a socio economic impact study of Adelaide Airport. The authors note that as noise is typically regarded as an undesirable neighbourhood characteristic, the hedonic price approach can be used to infer the impact of noise on house prices and by implication the effect on consumer welfare. Burns *et al* conclude that only where noise exposure levels are in excess of 25 ANEF residential property values are impacted by aircraft noise. While accepting that very few sales were recorded where ANEF levels were above 30 the study concluded that a 1-unit increase in noise exposure as measured by the ANEF index decreased property values on average by around 2.1 percent. The findings of the 1989 Adelaide Airport study, which were entirely in line with similar analyses undertaken at a number of overseas locations, suggested that the prices of houses beyond the 25 ANEF range were largely unaffected. The prices of approximately 2,000 dwellings within the 25 ANEF contour, however, were decreased on average by 10.7 per cent due to airport proximity.

In a survey of the hedonic price techniques and applications Streeting (1990) provides a summary of the Australian and overseas studies which had attempted, as of 1990, to quantify the impact of aircraft noise on house prices. According to Streeting, most of the Australian studies obtained reasonably consistent results with aircraft noise exerting a relatively small effect on property prices of 0 to 0.8 percent. The only Australian study that suggested that aircraft noise had a significant effect on house prices was the Burns *et al* 1989 study of Adelaide, results, which Streeting concluded were more consistent with those, found overseas. In the UK for high priced homes the effect per NEF unit change was 2.3 to 2.9 percent, for medium-priced homes 0.9 to 1.6 percent. In the US percentage impacts were of the order of 0.5 to 2.0 percent (Streeting 1990), in Canada 0.4 to 1.2 percent (in Streeting 1990) and in the Netherlands 0.8 to 1.1 percent (Opschoor 1986).

Methodology

Data

The study is based on the realised selling prices of residential homes for a section of Adelaide that runs from the beach in a northeast to easterly direction to the commencement of the Adelaide foothills. This section incorporates the Adelaide airport, suburbs directly under the flight path where ANEC's are greater than 20, suburbs surrounding the Adelaide airport, beach-side suburbs, and suburbs to the east of the Adelaide Central Business District. Figure 1 in the appendix displays the suburbs selected for the study.

Residential homes in the study area vary in respect of their physical attributes, neighbourhood and location characteristics, and are subject to varying levels of aircraft noise. As can be seen from the noise exposure contours shown on Figure 2 in the appendix, the study area contains a substantial collection of homes that would be expected to be completely unaffected by airport noise and proximity.

The registered selling prices of homes were extracted from the UPmarket sales database. UPmarket is a database developed and maintained by the University of South Australia. It contains all property transfers in South Australia that have been registered with the Lands Titles Office since 1981. Each transfer record includes: sale price, sale date, sale type, vendors name and address, purchasers name and address, property address, transfer document number, land use code and information that relates to the structural improvements included in the price. The following criteria was used for data extraction:

1. Transfers had to be registered with the Lands Titles Office between 1st January, 2000 and the 31st December, 2000
2. Properties transferred had to have a residential land use code where residential land uses include detached and attached houses
3. Properties were located in development zones where commercial and industrial use was not usually permitted
4. The sale price represented an open market transaction.

The Valuer-General maintains a database of the structural characteristics that relate to each improved residential property in South Australia. The Valuer-General receives advice of all building approvals lodged with local governments and this facilitates an inspection by trained field officers who update a property's record for any changes in the structural characteristics. The database is considered to be reliable and is used by the Valuer-General to establish, annually, property values for rating and taxing purposes. The structural characteristics recorded include building style, external wall material, roof material, year the home was built, building area of the home, general condition of the home, number of main living rooms, number of storeys, existence of en-suite bathroom, swimming pool, car garaging, sheds and tennis courts. This information is recorded against each sale.

Neighbourhood characteristics for each suburb were obtained from the Australian Bureau of Statistics 1996 Census of Population and Household Characteristics and the 1996 Social Atlas of Adelaide. Sales were subsequently assigned the neighborhood characteristics of the suburb in which they were located. Location characteristics for each sale were recorded as Euclidean distances from the centroid of each sale land parcel to various price influencing locational features such as beach, Adelaide CBD shopping precinct and the Adelaide airport. In addition, dummy variables were assigned to indicate if a sale property was located on the beachfront or within 1 kilometre of the beach. Finally a measurement of aircraft noise was assigned to each sale on the basis of the 1998 ANEC contour map.

The digital cadastral database (DCDB) for the study area was obtained from Land Information Group, Department of Administrative and Information Services. This spatial data base contains the property boundaries of all parcels of land created in South Australia and is the basis for managing all of the data for the study in a Geographic Information System (GIS). Other spatial data incorporated into the GIS was the ABS 1996 collector district boundaries, the 1998 ANEC contours, and the Adelaide metropolitan suburb boundaries. Managing all of the data in a GIS has the following advantages for this study:

1. The spatial join capability of GIS can be used to assign the appropriate ANEC level, neighbourhood and locational characteristics to the structural characteristic information contained on each sale property,
2. In addition to measuring locational influences as Euclidean distances they can also be measured by assigning dummy variables on the basis that a sale is located within the sphere of influence of the locational feature.

Models

The hedonic approach used involved identifying a range of physical and social characteristics of houses valued to various degrees by purchasers, and utilising data for a large number of recently marketed dwellings which included information on these characteristics, as well as actual selling price and proximity to the airport. Account was taken not only of travel distance to the airport, but also of 'proximity', defined in terms of 1998 ANEC contours.

The data comprising 4138 sales, are all probable market transactions of detached and semi-detached houses within residential zoning areas that occurred within the study area in 2000. The model specification and the variable selection criteria are based upon other relevant studies of residential housing markets in Adelaide that use the same databases. These studies by Rossini (1996,1997,1998,2000) all use hedonic regression models based on the same basic property characteristics. These characteristics have been found to produce robust models with only limited problems of multi-collinearity and heteroscedasticity. A standard set of property descriptors (Table 1) were used that include an estimate of building area and condition, distance to the city centre, beach front location, distance to the beach. A series of dummy variables were created to deal with site and building characteristics. Standard (0,1) interceptual dummies were used as well as interactive dummies created for all building characteristics by multiplying the interceptual dummy by the building area. The use of these interactive dummy variables have proven to be successful in more general linear hedonic price estimations of the Adelaide housing market. For these models relating to aircraft noise and associated affects, additional variables included distance to the airport terminal, dummy variables for ANEC levels and average household income for the local statistical collection district.

Table 1 – Independent variables used in the Analysis

Variables	Description
LAREA	Land Area in Square Metres
TENISCRT	Dummy variable to record if the property has a Tennis Court
SWIMPOOL	Dummy variable to record if the property has a swimming pool
HAREA	Calculated equivalent area of buildings based on weighted average formula for main buildings and other buildings (in square metres)
COND	Scaled code from 1 - Demolition level to 9 - high quality new condition
DISTMALL	Distance to Rundle Mall (CBD Shopping Zone) in metres
DISTAIR	Distance to the Airport in metres
M_INCOME	Average income level within the statistical collection district.
TFWALL	Dummy variable to record if external walls are timber framed
STWALL	Dummy variable to record if external walls are stone
ARCHIT	Dummy variable to record if the building has an Architect designed style
AUSTER	Dummy variable to record if the building has an Austerity style
BUNGALO	Dummy variable to record if the building has a Californian bungalow style
COLONIAL	Dummy variable to record if the building has a Colonial style
CONTEMP	Dummy variable to record if the building has a Contemporary style
SAHT	Dummy variable to record if the building Is a Traditional South Australian Housing Trust Design
COTTAGE	Dummy variable to record if the building has a Cottage style
MANSION	Dummy variable to record if the building is of Mansion style
RANCH	Dummy variable to record if the building has a Ranch style
TUDOR	Dummy variable to record if the building has a Tudor style
VILLA	Dummy variable to record if the building has a Villa style
GIROOF	Dummy variable to record if the roofing is galvanised iron
IMTILROF	Dummy variable to record if the roofing is imitation tile
SLATEROF	Dummy variable to record if the roofing is a slate product
ASBROOF	Dummy variable to record if the roofing is an asbestos product
ANEC20	Dummy variable to record if the property has an ANEC reading between 20 and 25
ANEC25	Dummy variable to record if the property has an ANEC reading between 25 and 30
ANEC30	Dummy variable to record if the property has an ANEC reading between 30 and 35
BECHFRNT	Dummy variable to record if the property is on the beach front
CLOSBEAC	Dummy variable to record if the property is within 1500 metres of the beach
SEMIDET	Dummy variable if the building is semi-detached
A_TFWAL	HAREA Multiplied by Dummy variable to record if external walls are timber framed
A_STWAL	HAREA Multiplied by Dummy variable to record if external walls are stone
A_ARCH	HAREA Multiplied by Dummy variable to record if the building has an Architect designed style
A_AUSTER	HAREA Multiplied by Dummy variable to record if the building has an Austerity style
A_BUNG	HAREA Multiplied by Dummy variable to record if the building has a Californian bungalow style
A_COLO	HAREA Multiplied by Dummy variable to record if the building has a Colonial style
A_CTEMP	HAREA Multiplied by Dummy variable to record if the building has a Contemporary style
A_SAHT	HAREA Multiplied by Dummy variable to record if the building Is a Traditional South Australian Housing Trust Design
A_COTT	HAREA Multiplied by Dummy variable to record if the building has a Cottage style
A_MANS	HAREA Multiplied by Dummy variable to record if the building is of Mansion style
A_RANCH	HAREA Multiplied by Dummy variable to record if the building has a Ranch style
A_TUDOR	HAREA Multiplied by Dummy variable to record if the building has a Tudor style
A_VILLA	HAREA Multiplied by Dummy variable to record if the building has a Villa style
A_GIROF	HAREA Multiplied by Dummy variable to record if the roofing is galvanised iron
A_IMTIL	HAREA Multiplied by Dummy variable to record if the roofing is imitation tile
A_SLROF	HAREA Multiplied by Dummy variable to record if the roofing is a slate product
A_ASBRF	HAREA Multiplied by Dummy variable to record if the roofing is an asbestos product
A_SEMID	HAREA Multiplied by Dummy variable if the building is semi-detached

Since this paper seeks to compare hedonic models the data set was separated into training and testing sets. This is a procedure used typically for model testing where regression and neural network models are compared (Worzalla, 1995, McCluskey, 1996 and Rossini, 1997). In this procedure the models are created using the training data. These models are then used to estimate the transaction price for the properties in the test data set. The accuracy is tested using the MAPE (mean absolute percentage error and the RMSE (root mean squared error). The data was randomly split into two-thirds for the training (modelling) and one third for the testing procedure.

Table 2 - Descriptive Statistics for the Test and Training samples

Variable	TRAIN (2756)	TEST (1383)
	Mean	
PRICE	$192,021	$196,467
LAREA	702	711
HAREA	141.50	144.06
COND	7.1	7.1
DISTAIR	8646	8565
DISTMALL	8449	8424
M_INCOME	$603.04	$ 598.92
	% of Sample	
ANEC20	2.10%	2.02%
ANEC25	0.73%	0.80%
ANEC30	0.11%	0.36%
BECHFRNT	0.58%	0.14%
CLOSBEAC	14.5%	16.0%
TENISCRT	0.4%	0.4%
SWIMPOOL	7.0%	8.0%

Descriptive statistics for the training and testing sets are shown in Table 1. These show that generally the test data is very similar to the training data and should provide a good picture of the accuracy of the models.

The models were specified in a linear and log-linear form. The linear form of the model assumes that there is a constant dollar amount for site and locational characteristics and a dollar per square metre effect for dwelling characteristics. Thus increases in one unit of noise result in a per unit house price depreciation whatever the level of noise might be. The log-linear form which assumes that noise is costed at a given percentage of house price, was used in the initial work by Burns et al (2001) and is commonly used in hedonic price estimates to derive percentage effects for each variable. Models in both the linear and log-linear form were estimated using ordinary least squares multiple regression analysis (MRA) and artificial neural networks (ANN). The ANN models were specified in two groups. The first group used the most basic network structure involving no hidden layers. This is the structure most analogous to a regression model. The network structure was then applied using the Linear, Sigmoid, Hyperbolic and Gaussian activation functions. As a final step a genetic algorithm was used to select the best network structure and learning parameters.

Once each model was estimated the implied effect of being located in each of the different ANEC regions was measured and can be calculated directly from the model in some cases. However in order to compare the linear and log-linear models it is useful to calculate the effect for properties at different ends of the property price spectrum. To do this a hypothetical "typical" low priced and high priced property were used for estimates. This enables the comparison at both a dollar and percentage value for properties near each end of the spectrum.

Results

The hedonic models produce results that are typical for the Adelaide housing market given the available data set. The regression coefficients are consistent with the previous research and model statistics such as R squared and F values are as expected with models that use a limited set of property characteristics. The results from the models are presented in full in the appendix. The log-linear model using the whole data set is shown in Table 4 with the corresponding model with just the training set in Table 5. The linear models are shown as Table 6 & Table 7 in the appendix. Statistically the models are reasonably sound with low levels of multi-collinearity as indicated by most variance inflation factors (VIF) being in the 1 to 2 range with no variables with a large VIF. In each of the log-linear models all of the ANEC dummies are significantly different from 0. This is not the case in either of the linear models. This is superficial justification for accepting the log-linear rather than linear model.

The summary of the implied linear and percentage effects from each model are shown in Table 3.

There are several noticeable features of the model results.

- The log-linear models always produce lower MAPE's than the equivalent linear model. However the linear models often produce lower or similar RMSE's. This suggests that while on average the percentage errors are lower in the log-linear model, that there are some very large errors which are highlighted by the squared nature of the RMS error estimate.
- Every estimate is negative. This provides further evidence that there is a significant negative effect of aircraft noise on residential property values. Based on the log linear regression estimate the per unit price depreciation for properties within the 20 and 25 ANEC is on average 1.9% for both high and low priced properties. This approximates earlier findings by Burns (1989) for Adelaide, is close to results for the US and Canada (Streeting 1990) and is somewhat lower than for the UK. For properties lying within the 30 ANEC the per unit depreciation based on the same model is considerably higher at over 3% which is similar to results from the UK for higher priced homes. When measured in dollars it amounts to a considerable loss in value.
- The ANN models seem to suggest lower variations between the ANEC groups. While both regression models show that the effect in the 30 ANEC region is about twice that of the 20 ANEC region the ANN models do not support this. They show variable patterns depending upon the model but generally not the same degree of difference between the ANEC groups.
- The ANN models suggest that broadly the results are somewhere between the two regression models. In general the linear regression model tends to over estimate the impact for low priced properties and under estimate for the high priced ones while the log-linear does the opposite. This suggests that a model in between may be a better option. This is clearly supported by the results from the ANN models.
- A reasonable conclusion might be that the correct model specification would include an interceptual and a slope variation for each ANEC group perhaps represented by a fixed dollar amount (which might reasonably be attached to the land) and a percentage amount that will vary with the extent and quality of the buildings.

Concluding Remarks

A focus of this paper was to consider how improving the structural form of the relationship between residential property prices and aircraft noise as measured by ANEC levels might be a means of improving compensation outcomes. The paper provides strong evidence of the negative relationship between noise and residential property prices. Regardless of the modelling methodology, a negative relationship was found. The paper further explores the structural form of the relationship. While the nature of the relationship is not readily expressed as either a single dollar effect or a fixed percentage effect, it is noticeable that models that imply a percentage effect are superior to those that suggest a fixed dollar effect. The use of ANN where the model can move towards its own structural form suggest that an appropriate expression may exist somewhere between the two models.

It is expected that future research will need to formulate an appropriate structural form that can be estimated also through traditional econometric methods. Further analysis of the modelling outcomes could offer assistance in demarcating those areas best qualified to receive compensation payouts.. The undertaking of a survey would allow for a better understanding of the decision making process of purchasers within the airport locality. As well a broader application of GIS to the analysis could more closely account for the wider location influences on property values and also enable modelling of the aggregate price affect caused by aircraft noise on all properties within the affected location.

Table 3 - Results from various models for the effect of aircraft noise

Method		Effect	Low Price Property			High Price Property			Error Terms based on Test Sample	
			ANEC 20	ANEC 25	ANEC 30	ANEC 20	ANEC 25	ANEC 30	MAPE	RMSE
Linear-Linear	Regression	%	-20.6%	-18.5%	-39.1%	-2.1%	-1.9%	-4.0%	30.6%	$ 70,125
		$	-$ 19,761	-$ 17,779	-$ 37,561	-$ 19,761	-$ 17,779	-$ 37,561		
	ANN - 2 Layers Linear	%	-20.9%	-27.0%	-19.8%	-1.6%	-2.1%	-1.6%	20.9%	$ 61,225
		$	-$ 14,677	-$ 18,949	-$ 13,874	-$ 14,677	-$ 18,949	-$ 13,874		
	ANN - 2 Layers Sigmoid	%	-8.5%	-14.1%	-8.1%	-1.7%	-3.0%	-1.7%	23.8%	$ 63,686
		$	-$ 9,559	-$ 15,904	-$ 9,179	-$ 16,919	-$ 29,016	-$ 16,284		
	ANN - 2 Layers Hyperbolic	%	-7.1%	-10.4%	-9.7%	-1.4%	-2.1%	-2.0%	27.3%	$ 67,927
		$	-$ 8,163	-$ 11,973	-$ 11,236	-$ 13,826	-$ 20,608	-$ 19,280		
	ANN - 2 Layers Gaussian	%	-10.7%	-12.6%	-11.5%	-2.6%	-3.1%	-2.8%	20.6%	$ 60,977
		$	-$ 10,744	-$ 12,689	-$ 11,547	-$ 25,590	-$ 30,412	-$ 27,536		
	ANN - MAXIMIZED 4 Layers Sigmoid	%	-4.9%	-13.3%	-12.6%	-1.7%	-5.2%	-7.1%	18.2%	$ 62,646
		$	-$ 4,526	-$ 12,351	-$ 11,716	-$ 14,889	-$ 44,328	-$ 58,159		
Log-Linear Models	Regression	%	-9.6%	-9.7%	-18.1%	-9.6%	-9.7%	-18.1%	17.4%	$101,684
		$	-$ 9,299	-$ 9,482	-$ 17,644	-$ 115,026	-$ 117,291	-$ 218,258		
	ANN - 2 Layers Linear	%	-7.3%	-5.9%	-5.5%	-7.3%	-6.3%	-5.8%	21.3%	$ 65,374
		$	-$ 8,034	-$ 6,524	-$ 6,131	-$ 117,919	-$ 95,041	-$ 89,268		
	ANN - 2 Layers Sigmoid	%	-8.5%	-4.2%	-13.2%	-3.1%	-1.5%	-5.0%	19.7%	$ 60,730
		$	-$ 9,013	-$ 4,488	-$ 13,944	-$ 30,483	-$ 14,679	-$ 48,228		
	ANN - 2 Layers Hyperbolic	%	-6.1%	-6.9%	-8.5%	-2.4%	-2.7%	-3.4%	21.1%	$ 61,994
		$	-$ 6,906	-$ 7,833	-$ 9,618	-$ 22,036	-$ 25,073	-$ 30,976		
	ANN - 2 Layers Gaussian	%	-4.7%	-7.0%	-9.7%	-2.7%	-4.2%	-6.0%	19.2%	$ 63,521
		$	-$ 5,215	-$ 7,704	-$ 10,710	-$ 31,688	-$ 47,172	-$ 66,198		
	ANN - MAXIMIZED 3 Layers Sigmoid	%	-6.0%	-4.9%	-1.6%	-2.7%	-2.2%	-0.7%	19.3%	$ 59,246
		$	-$ 7,023	-$ 5,726	-$ 1,905	-$ 27,508	-$ 21,778	-$ 6,825		

NOTE: Shaded figures are implied from the models (for low and high priced properties) while non-shaded figures are derived directly from the model coefficients. A low priced property is defined as a conventional styled brick home in average condition of 100 sq metre on a 500 sq metre site in a low income area in a mid suburban location. High priced property is defined as a conventional styled brick home in excellent condition of 500 sq metre on a 4000 sq metre site with a swimming pool and tennis court, in the highest income area in a mid suburban location.

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Appendix

Figure 1 - Adelaide Metropolitan Area – Key Aspects of the Study Area

Figure 2 - Adelaide Airport – ANEC Contours, 1998

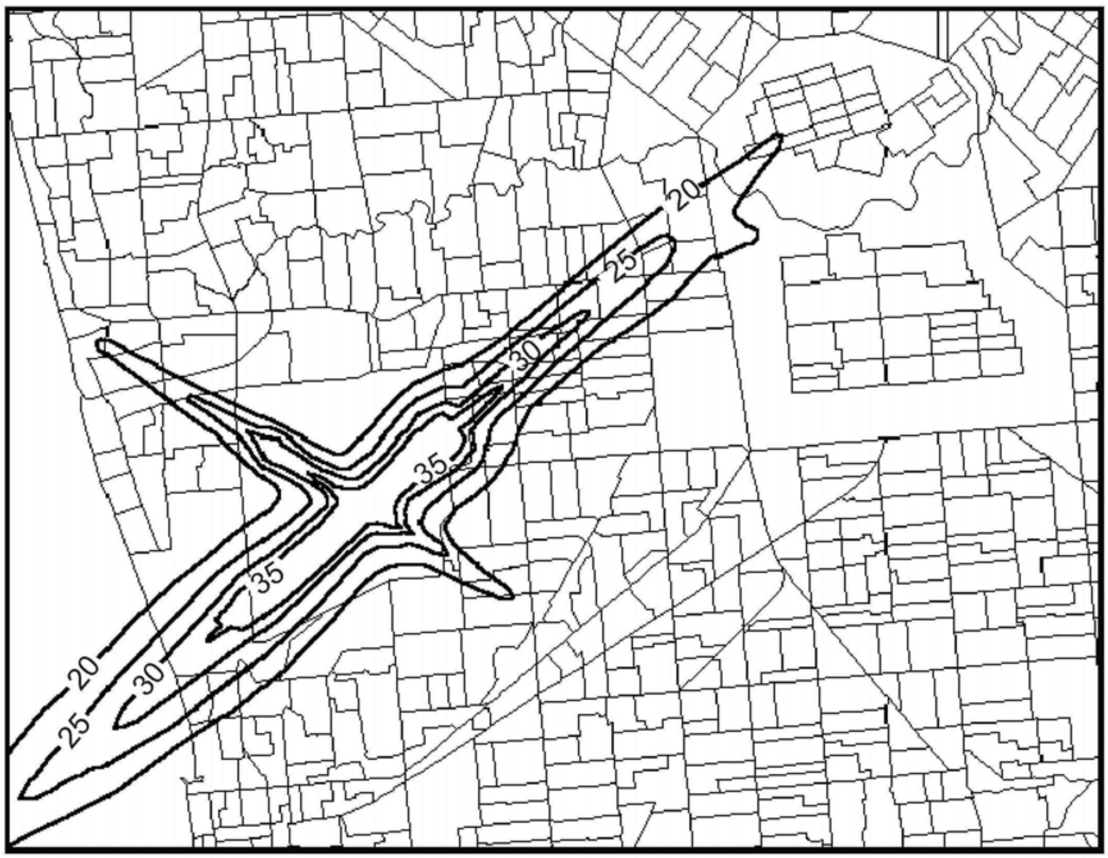

Table 4 - Regression Model - LN Price against Selected Variables (All data)

R Square	0.7501
Adjusted R Square	0.7482
Std. Error of the Estimate	0.2130

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	559.5247	31	18.0492	397.9556	0
Residual	186.2720	4107	0.0454		
Total	745.7968	4138			

Dependent Variable: LNPRICE

Coefficients

	B	Std. Error	t	Sig.	VIF	Equation	% Effect	95% Sig
(Constant)	11.1233	0.0297	374.2790	0.0000		67729.67		
LAREA	0.0002	0.0000	10.5278	0.0000	1.5191	1.0002	0.02%	*
TENISCRT	0.1061	0.0567	1.8707	0.0615	1.2005	1.1119	11.19%	
SWIMPOOL	0.0412	0.0136	3.0419	0.0024	1.1382	1.0421	4.21%	*
HAREA	0.0041	0.0001	49.2996	0.0000	1.7767	1.0041	0.41%	*
COND	0.0399	0.0039	10.3218	0.0000	1.6199	1.0407	4.07%	*
DISTAIR	0.0000	0.0000	-1.6781	0.0934	1.6930	1.0000	0.00%	
DISTMALL	0.0000	0.0000	-34.3813	0.0000	2.1617	1.0000	0.00%	*
M_INCOME	0.0004	0.0000	19.3519	0.0000	1.4292	1.0004	0.04%	*
TFWALL	-0.1345	0.0177	-7.5997	0.0000	1.2273	0.8741	-12.59%	*
STWALL	0.0515	0.0108	4.7514	0.0000	1.1630	1.0529	5.29%	*
ARCHIT	0.1413	0.0326	4.3313	0.0000	1.1359	1.1518	15.18%	*
AUSTER	-0.0690	0.0151	-4.5847	0.0000	1.1651	0.9333	-6.67%	*
BUNGALO	0.1013	0.0145	7.0090	0.0000	1.8508	1.1066	10.66%	*
COLONIAL	0.0673	0.0156	4.3010	0.0000	1.1335	1.0696	6.96%	*
CONTEMP	-0.0549	0.0188	-2.9144	0.0036	1.1881	0.9466	-5.34%	*
SAHT	0.0292	0.0157	1.8564	0.0635	1.2082	1.0296	2.96%	
COTTAGE	0.1409	0.0192	7.3301	0.0000	1.4462	1.1513	15.13%	*
MANSION	0.1424	0.1115	1.2774	0.2015	1.0950	1.1530	15.30%	
RANCH	-0.0404	0.0247	-1.6327	0.1026	1.0315	0.9604	-3.96%	
TUDOR	0.2187	0.0296	7.3784	0.0000	1.0700	1.2444	24.44%	*
VILLA	0.1595	0.0173	9.2387	0.0000	1.5377	1.1729	17.29%	*
GIROOF	-0.0171	0.0108	-1.5786	0.1145	2.0729	0.9830	-1.70%	
IMTILROF	-0.0649	0.0163	-3.9854	0.0001	1.4139	0.9372	-6.28%	*
SLATEROF	-0.0007	0.0781	-0.0084	0.9933	1.0742	0.9993	-0.07%	
ASBROOF	0.0698	0.0239	2.9137	0.0036	1.1134	1.0723	7.23%	*
ANEC20	-0.1209	0.0240	-5.0402	0.0000	1.0677	0.8862	-11.38%	*
ANEC25	-0.0793	0.0389	-2.0391	0.0415	1.0266	0.9237	-7.63%	*
ANEC30	-0.1818	0.0759	-2.3941	0.0167	1.0148	0.8338	-16.62%	*
BECHFRNT	0.9024	0.0518	17.4255	0.0000	1.0596	2.4654	146.54%	*
CLOSBEAC	0.2410	0.0112	21.5472	0.0000	1.4540	1.2725	27.25%	*
SEMIDET	-0.0174	0.0153	-1.1356	0.2562	1.2570	0.9828	-1.72%	

Dependent Variable: ln of transaction price

Table 5 - Regression Model - LN Price against Selected Variables (Training Data)

R Square	0.7626
Adjusted R Square	0.7599
Std. Error of the Estimate	0.2065

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	373.1788	31	12.0380	282.3417	0
Residual	116.1415	2724	0.0426		
Total	489.3204	2755			

Dependent Variable: LNPRICE

Coefficients

	B	Std. Error	t	Sig.	VIF	Equation	% Effect	95% Sig
(Constant)	11.1242	0.0352	315.7460	0.0000		67795.11		
LAREA	0.0002	0.0000	8.5487	0.0000	1.5008	1.0002	0.02%	*
TENISCRT	0.1617	0.0729	2.2176	0.0267	1.3658	1.1755	17.55%	*
SWIMPOOL	0.0580	0.0163	3.5608	0.0004	1.1110	1.0597	5.97%	*
HAREA	0.0043	0.0001	41.9695	0.0000	1.7404	1.0043	0.43%	*
COND	0.0361	0.0046	7.8428	0.0000	1.6499	1.0368	3.68%	*
DISTAIR	0.0000	0.0000	-1.7980	0.0723	1.6863	1.0000	0.00%	
DISTMALL	0.0000	0.0000	-28.4154	0.0000	2.1647	1.0000	0.00%	*
M_INCOME	0.0004	0.0000	16.2810	0.0000	1.4416	1.0004	0.04%	*
TFWALL	-0.1383	0.0207	-6.6794	0.0000	1.2646	0.8708	-12.92%	*
STWALL	0.0447	0.0129	3.4722	0.0005	1.1591	1.0457	4.57%	*
ARCHIT	0.1281	0.0372	3.4462	0.0006	1.1520	1.1367	13.67%	*
AUSTER	-0.0616	0.0177	-3.4826	0.0005	1.1894	0.9403	-5.97%	*
BUNGALO	0.1002	0.0175	5.7410	0.0000	1.8485	1.1054	10.54%	*
COLONIAL	0.0630	0.0182	3.4655	0.0005	1.1460	1.0650	6.50%	*
CONTEMP	-0.0173	0.0223	-0.7754	0.4382	1.1630	0.9829	-1.71%	
SAHT	0.0331	0.0188	1.7636	0.0779	1.2185	1.0337	3.37%	
COTTAGE	0.1128	0.0230	4.9024	0.0000	1.4692	1.1194	11.94%	*
MANSION	0.0875	0.1687	0.5188	0.6039	1.3343	1.0915	9.15%	
RANCH	-0.0423	0.0302	-1.3979	0.1622	1.0316	0.9586	-4.14%	
TUDOR	0.2265	0.0381	5.9435	0.0000	1.0437	1.2542	25.42%	*
VILLA	0.1688	0.0205	8.2242	0.0000	1.5405	1.1838	18.38%	*
GIROOF	-0.0131	0.0128	-1.0292	0.3035	2.0372	0.9869	-1.31%	
IMTILROF	-0.0714	0.0195	-3.6573	0.0003	1.4258	0.9311	-6.89%	*
SLATEROF	-0.1816	0.1136	-1.5987	0.1100	1.2087	0.8339	-16.61%	
ASBROOF	0.1112	0.0295	3.7654	0.0002	1.1218	1.1176	11.76%	*
ANEC20	-0.1004	0.0284	-3.5409	0.0004	1.0704	0.9045	-9.55%	*
ANEC25	-0.1025	0.0469	-2.1847	0.0290	1.0245	0.9026	-9.74%	*
ANEC30	-0.2000	0.1199	-1.6675	0.0955	1.0107	0.8188	-18.12%	
BECHFRNT	0.9773	0.0538	18.1559	0.0000	1.0811	2.6573	165.73%	*
CLOSBEAC	0.2335	0.0134	17.3722	0.0000	1.4454	1.2630	26.30%	*
SEMIDET	-0.001	0.01806381	-0.05533	0.955883	1.280934	0.9990	-0.10%	

Dependent Variable: ln of transaction price

Table 6 - Regression Model - Price against Selected Variables (All Data)

R Square	0.7627
Adjusted R Square	0.7609
Std. Error of the Estimate	52114

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	3.59E+13	31	1.16E+12	425.9052	0
Residual	1.12E+13	4107	2.72E+09		
Total	4.7E+13	4138			

Dependent Variable: PRICE

Coefficients

	B	Std. Error	t	Sig.	VIF	Estimate	95% Sig
(Constant)	-35529.9	6884.90976	-5.16055	2.58E-07			
LAREA	48.53746	3.92012538	12.38161	2.81E-23	1.497416	$48.5	*
TENISCRT	179182.7	14200.6227	12.61795	2.81E-23	1.25711	$179,182.7	*
SWIMPOOL	16982.81	3321.13424	5.113557	3.31E-07	1.140501	$16,982.8	*
HAREA	954.8774	22.1238534	43.16054	2.81E-23	2.074952	$954.9	*
COND	7088.012	928.894505	7.630588	2.89E-14	1.564209	$7,088.0	*
DISTAIR	-0.27286	0.24052935	-1.13441	0.25669	1.680777	-$0.3	
DISTMALL	-7.90416	0.28564807	-27.671	2.81E-23	2.120026	-$7.9	*
M_INCOME	95.07193	5.30132013	17.93363	2.81E-23	1.421402	$95.1	*
ANEC20	-25962.4	5857.49567	-4.43235	9.56E-06	1.063899	-$25,962.4	*
ANEC25	-16044.6	9495.87031	-1.68964	0.091172	1.021558	-$16,044.6	
ANEC30	-42681.8	18580.7029	-2.29711	0.021663	1.015012	-$42,681.8	*
BECHFRNT	283934.1	12666.2357	22.41661	2.81E-23	1.058697	$283,934.1	*
CLOSBEAC	45445.06	2733.52429	16.62508	2.81E-23	1.450302	$45,445.1	*
A_TFWAL	-44.4644	39.4853353	-1.1261	0.260189	1.145484	-$44.5	
A_STWAL	61.66097	17.0288322	3.620975	0.000297	1.25821	$61.7	*
A_ARCH	274.2498	34.3878098	7.975203	1.96E-15	1.22742	$274.2	*
A_AUSTER	-42.9859	30.9882892	-1.38717	0.165466	1.123043	-$43.0	
A_BUNG	210.5464	22.7278151	9.26382	3.1E-20	1.724223	$210.5	*
A_COLO	108.5615	21.3114596	5.094041	3.66E-07	1.207434	$108.6	*
A_CTEMP	-86.3313	27.6608427	-3.12106	0.001815	1.221342	-$86.3	*
A_SAHT	104.4811	34.4150716	3.03591	0.002413	1.164227	$104.5	*
A_COTT	290.3279	33.6747438	8.621533	9.29E-18	1.35189	$290.3	*
A_MANS	511.7953	87.9711466	5.817764	6.42E-09	1.173396	$511.8	*
A_RANCH	-102.087	36.7341415	-2.77908	0.005476	1.038523	-$102.1	*
A_TUDOR	417.7058	36.2005764	11.53865	2.81E-23	1.091298	$417.7	*
A_VILLA	312.1291	25.1855169	12.3932	2.81E-23	1.702868	$312.1	*
A_GIROF	-20.6026	16.7690732	-1.22861	0.219289	1.999263	-$20.6	
A_IMTIL	-89.5464	28.1053562	-3.1861	0.001453	1.317766	-$89.5	*
A_SLROF	365.2618	66.2340011	5.514718	3.71E-08	1.152638	$365.3	*
A_ASBRF	156.8869	38.2510228	4.10151	4.18E-05	1.147562	$156.9	*
A_SEMID	96.52179	28.3906162	3.399778	0.000681	1.237448	$96.5	*

Table 7 - Regression Model - Price against Selected Variables (Training Data)

R Square	0.7839
Adjusted R Square	0.7814
Std. Error of the Estimate	48705

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	2.34E+13	31	7.56E+11	318.7226	0
Residual	6.46E+12	2724	2.37E+09		
Total	2.99E+13	2755			

Dependent Variable: PRICE

Coefficients

	B	Std. Error	t	Sig.	VIF	Estimate	95% Sig
(Constant)	-38332.5	7877.03666	-4.86636	1.2E-06			
LAREA	48.71864	4.48954221	10.85158	3.8E-23	1.485848	$48.7	*
TENISCRT	137394.4	17608.7731	7.802608	8.57E-15	1.432102	$137,394.4	*
SWIMPOOL	22912.4	3840.97118	5.965261	2.76E-09	1.110918	$22,912.4	*
HAREA	969.1278	25.7597909	37.62173	3.8E-23	1.98721	$969.1	*
COND	6726.502	1066.3681	6.307861	3.29E-10	1.59155	$6,726.5	*
DISTAIR	-0.34998	0.27406605	-1.277	0.201711	1.671194	-$0.3	
DISTMALL	-7.45879	0.32572038	-22.8994	3.8E-23	2.122001	-$7.5	*
M_INCOME	91.33618	6.04730735	15.10361	3.8E-23	1.432546	$91.3	*
ANEC20	-19761.4	6669.89322	-2.96277	0.003075	1.06485	-$19,761.4	*
ANEC25	-17778.7	11045.0271	-1.60965	0.10759	1.021081	-$17,778.7	
ANEC30	-37560.9	28243.931	-1.32988	0.18367	1.007763	-$37,560.9	
BECHFRNT	300491.5	12675.3463	23.70677	3.8E-23	1.077385	$300,491.5	*
CLOSBEAC	43780.09	3166.78723	13.82477	3.8E-23	1.442617	$43,780.1	*
A_TFWAL	-72.4417	45.0634602	-1.60755	0.10805	1.176176	-$72.4	
A_STWAL	79.24453	20.3550261	3.893119	0.000101	1.283865	$79.2	*
A_ARCH	266.8578	38.9213323	6.856339	8.71E-12	1.235498	$266.9	*
A_AUSTER	-16.4277	36.1294406	-0.45469	0.649369	1.14667	-$16.4	
A_BUNG	191.7879	27.3305568	7.017345	2.84E-12	1.765623	$191.8	*
A_COLO	107.558	23.9563722	4.489744	7.43E-06	1.239862	$107.6	*
A_CTEMP	7.392947	32.9496656	0.224371	0.822486	1.163606	$7.4	
A_SAHT	117.6051	39.7224571	2.960672	0.003096	1.168725	$117.6	*
A_COTT	235.0547	38.8075242	6.056936	1.58E-09	1.422816	$235.1	*
A_MANS	825.6423	110.799897	7.451653	1.23E-13	1.441363	$825.6	*
A_RANCH	-108.586	42.1074743	-2.57877	0.009967	1.041289	-$108.6	*
A_TUDOR	433.9999	47.2765652	9.180021	8.29E-20	1.052401	$434.0	*
A_VILLA	311.9381	29.5337277	10.5621	3.8E-23	1.735408	$311.9	*
A_GIROF	-1.21786	19.388171	-0.06281	0.949919	2.001084	-$1.2	
A_IMTIL	-72.4435	33.3608582	-2.17151	0.029979	1.384507	-$72.4	*
A_SLROF	176.3033	87.2595248	2.020448	0.043435	1.37079	$176.3	*
A_ASBRF	264.1856	45.3124353	5.830311	6.18E-09	1.190325	$264.2	*
A_SEMID	119.5618	32.3267496	3.69854	0.000221	1.269096	$119.6	*

Dependent Variable: transaction price