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Measuring the changing effects of aircraft noise a case study of Adelaide Airport

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Abstract: This study extends previous research into the impact of aircraft noise upon residential property values by investigating how these impacts have changed over time. The study, which uses a dynamic hedonic pricing framework, draws on recent developments in the use of Geographic Information Systems in merging geographic and textural data. This makes manageable the large data sets inherent in a study of this kind. A modelling framework is developed to that takes into account the need to differentiate between 'true' taste change effects and household responses to general price and income effects. Preliminary results support the notion that tastes do change, in the manner that behaviouralists sometimes suggest that individuals may become accustomed to various stimuli, such as noise.

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 the present paper that explores whether and how the impact of airport noise and proximity on residential property values has changed over time.

Although the results reported in this paper are exploratory in nature, we believe several aspects of the research so far are of interest. First, the paper makes use of Geographic Information Systems (GIS) technology and illustrates the power of this tool in merging geographic and textural data and in handling large data sets. Second, some insights are derived as to the significant changes that can occur in the measured impact of airport noise and proximity upon residential property prices over relatively short time periods. These measured changes, of course, can occur for a variety of reasons. They could reflect: actual changes in householders perceptions and responses to aircraft noise and airport proximity; compositional problems associated with the use of a composite single index of noise exposure; genuine "taste" changes as, for example, people become more accustomed to given noise exposure levels; and, errors arising in the measurement of noise exposure from one period to another. These issues are not fully explored here but will be the subject of further research.

Independently of the reasons for apparent changing impacts of noise upon residential property values, the results presented here are of interest for a third reason. Whenever airports are located in an urban environment public debate invariably arises as to whether the disamenity effects of airport proximity are so large as to justify relocation to a more remote site. In the case of Adelaide International Airport, its location had been determined on a reasonably permanent basis because of earlier research, Burns et el (1989). Here it had demonstrated both that there was a clear case for retaining the existing location and that the monetary value of the negative impact of airport noise and proximity upon the local community played an insignificant role in overall cost-benefit calculations. Even though the findings here suggest that the monetary value of these airport impacts may have doubled over a period of five years, it appears that the impact of airport noise and proximity upon residential property values still deserves only a very minor role in decisions regarding the location of the airport.

The paper develops as follows. A literature review presented in Section two addresses early economic considerations regarding the impact of noise, the measurement of noise exposure as well as surveying some of the empirical evidence as to the monetary impact on property values associated with measured noise exposure levels. This is followed in Section three with a brief discussion of the location characteristics of Adelaide International Airport and suggestions as to why the study of the impacts of airport proximity at this location may be of general interest and relevance. Section four provides details of data sources while Sections five and six describes in more detail the research methodology used here and reports on the empirical results obtained. A concluding section summarises the more useful insights that can be derived from the research so far and indicates the directions where further research is required.

Literature Review

The literature review presented here is not exhaustive, but selects elements from the three strands that bear upon our analysis here. 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 values.

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.

Noise contours will change over time due to changes in any of the underlying factors mentioned above and the exploration of the nature and impact of these changes is a major purpose of the research underlying this paper. In this research use is actually made of the ANEC system because contours using this measure are available for a greater number of time periods. 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. Providing the predicted value that underlies some ANEC contours are in close agreement with events that actually transpired, these contours might be 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 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 (e.g. Pommerehne (1986, 1987), Burns et al (1989), Streeting (1990) and 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) reports 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. For homes subject to 25 ANEF or greater prices on average will be 10.7% lower than if the property lay outside the 25 contour. Bearing mind that very few sales were recorded where ANEF levels were above 30 it appeared that a 1-unit increase in noise exposure as measured by the ANEF index decreases property values on average by around 2.1 percent

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).

Alternative approaches have been considered in the more recent literature. Rossini (1997, 1998) has explored the use of artificial neural networks, as have Pitt and Jones for the UK (2000) but questions remain as to the comparative accuracy of the two techniques. A further approach that is perhaps worth considering is the marketing research tool of choice-based-conjoint analysis.

An important issue when considering aircraft noise is that the relative depreciating influence of noise may change over time. The gap between the price of quiet houses and price of noisy houses may increase over time not only absolutely but also relatively. This widening will be due to the fact that as incomes grow over time and if residential quiet is a luxury good, the relative scarcity of quiet environments would be expected to increase. Another issue is the likelihood that more expensive homes will be more severely impacted relative to less expensive. Both of these issues will be considered in further research.

Adelaide International Airport: Location And Relevance

Metropolitan Adelaide has a population of over one million people 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. Two issues are of relevance to the present paper: the justification for the airport's location as well as the consequence expectation that the airport will not be re-located in the foreseeable future; and, the reasons why a study of the impacts of the noise and proximity impacts associated with AIA may have relevance for other airports worldwide. Figure 1 in Appendix 1 in shows a map of metropolitan Adelaide that also indicates the relative positioning of the coast, the airport, the city centre and the backdrop of the Adelaide Hills.

The Location of Adelaide International Airport

For a city the size of Adelaide it is-unusual to find an airport located within the urban concentration-and so close to the city centre. It is also unusual that the case for retaining such an airport location has been so strongly supported, as was the case following the very detailed considerations in the earlier Burns *et al* study. This study, which was based upon consideration of current and best alternative airport locations, took into account a range of considerations besides the negative impacts of aircraft noise and airport proximity upon residential property values. These included the value of alternative use of current airport land, urban consolidation issues, the costs associated with the physical relocation of the airport and the increase in time and other travel costs to existing airport users that would result from airport relocation.

The Impact Of Airport Proximity On Residential Property Values

Recent purchase prices would have reflected the near certainty that the airport will retain its current location into the foreseeable future. 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 noise contours determined by the former Department of Aviation as measures of subjective noise levels, Noise Exposure Forecasts (ANEFs).

The principle underlying the statistical analysis is that if you can accurately determine the value of two dwellings which are essentially identical in all major respects except that one is completely unaffected by airport-noise and the other is located, for example, on a 30 NEF contour, then the difference in purchase prices will reflect the 'nuisance value' associated with airport proximity. 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 NEF range were largely unaffected. The prices of approximately 2,000 dwellings within the 25 NEF contour, however, were decreased on average by 10.7 per cent due to airport proximity as measured by NEFs. The resulting upper bound on this airport 'nuisance value' was estimated at $30 million in 1989 prices. As it turned out, this cost was of an order of magnitude so small as to be almost totally irrelevant to the benefit-cost analysis of airport location. It is useful to outline the other key financial magnitudes that determine the optimal location of Adelaide International Airport.

The Alternative Use of Airport Land and Urban Consolidation

In the 1989 study it was recognised that the existing airport land would have a significant value if made available for residential use. Compared to other cities, however, even land close to both the city and the beach is relatively abundant in Adelaide and the net value, taking into account the costs of the removal of existing airport infrastructure, had been estimated by the local Real Estate Institute to be between $400 million and $700.

Account was also taken 'of the possibility of gains to relocating the airport due to 'urban consolidation'. The savings associated with consolidation arise from availability of infrastructure, including schools as well as utility services, in the airport location but which would have to be provided in the newer housing development areas. The value of these savings was estimated to be in the range $100 million to $150 million.

Costs Associated with an Alternative Airport Location

Two types of these costs were identified in the earlier study: the time and travel costs incurred by airport users having to travel to the new and more distant airport location; and, the costs of land purchase as well as airport and access infrastructure at least to a standard of the existing facilities. The alternative location was assumed to be the Two Wells-Viriginia site recommended-by-the Joint Government Advisory Committee and incorporated in the Adelaide Airport Provisional Master Plan. This site was located some 30 kilometres north of the Adelaide city centre.

A number of factors were taken into account in estimating the first type of costs. These included the number of persons making time savings, where in the Adelaide environs these persons travelled from, two independent estimates of the value of time savings to these persons and the additional resource costs associated with additional travel. The calculations took into account the mix of airline passengers, the cost of labour associated with taxi and coach travel as well as the 'full cost per kilometre' for the additional vehicle use associated with the additional travel. No account, however, was taken of the time and travel cost savings associated with non-flying airport visitors.

In 1989 the sum of these costs was estimated to have a present value of between $0.8 and $1.2 billion dollars. It is of interest that four years later, largely due to a 35% increase in passenger traffic and a 67% increase in fuel costs, had blown out to a figure between $1.4 and $2.3 billion dollars. The further costs associated with airport relocation would involve land purchase, replication of the existing level of facilities and provision of the infrastructure. In the 1989 study these costs were estimated to be of the order of $650 million to $800 million.

In Table 1 are summarised the major identifiable benefits and costs associated with a relocation of Adelaide Airport and it is clear both how strongly the current location is justified and how minor is the role of airport noise in determining airport location. If the case for airport relocation was weak in 1989 then the case today is almost certain to be even weaker. The changes to the major factors that have occurred since the earlier study all work so as to substantially increase the costs associated with an airport more remote from the city centre.

The time and travel costs associated with relocation of Adelaide International Airport to its best alternative site will have continued to increase disproportionately over time, due to increased passenger traffic and further increases in the real cost of energy. The relatively smaller increase in the value of residential use of the airport land is quite insufficient to compensate for these other effects and, in any case, increases in land value will also increase the purchase costs of an alternative-site. The expectation of those involved in housing market decisions must be that Adelaide Airport will remain at its current location. For this reason we can be reasonably confident that any changes local residential property prices identified in the current study have not been brought about by speculation regarding the possible relocation of the airport and the associated windfall gains to landowners.

Table 1 - 1989 Estimates of Benefits and Costs Associated with Relocation of Adelaide Airport to New-Site at Two-Wells-Virginia

	ESTIMATED -BENEFITS	
1.	Elimination of costs currently imposed upon households by aircraft noise and airport proximity	$25m - $30m
2.	Net increase in value of airport land, incorporating value of time and travel cost due to new residents	$400m - $700m
3.	Gain due to urban consolidation considerations	$100m - $150m
	Total Identifiable Benefits	**$450m - $840m**
	ESTIMATED COSTS	
1.	Present value of increase in time and travel costs to existing users of the airport	$800m - $1200m
2.	Cost of replicating existing facilities, including purchase of land	$650m - $800m
	Total Identifiable Costs	**$1450m - $2000m**
	Net Benefits	**$1000m - $1160m**

Notes The benefits assume that the increase in value of the airport land occurs immediately. In reality the lags in development would reduce the present value of the land br$20m - $30m.
The costs are almost certainly underestimated by a significant amount, no account being taken of items such as: additional time and travel costs of persons other than passengers (the present value could exceed $500rn), costs of >upgrading road and other transport facilities for Two Wells access, etc.

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 ANEF'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 Appendix 1 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 Appendix 1, 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, 1995 and the 31st December, 1995, or 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, flats and home units

3. 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.

Neighborhood 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 GPO, Adelaide airport, shopping and entertainment areas. In addition, dummy variables were assigned to indicate if a sale property was located on a main road or beachfront. Finally, for the initial exploratory research reported here, aircraft noise as reflected in the Department of Aviation's index of noise nuisance, Australian Noise Exposure Forecast, was assigned to each sale on the basis of the 1998 ANEC contour map.

This map was used to categorise both 1995 and 2000 residential property sales and a word of explanation is in order. In future research it is intended to use ANEC contours derived specifically for the years in which particular sales takes place. Historically in Adelaide, however, airport related noise exposures have been affected in large part by two competing forces. On the one hand there has been a significant increase in the number of both passengers and flights. On the other hand, aircraft have become quieter, for example due to the improved engine technology manifested in the Boeing 737 as opposed to the Boeing 727 that it has replaced. Over the period 1995 to 2000 the result of these competing impacts has been to keep the noise exposures approximately constant so that the 1995 ANEC contours are virtually identical to the 2000 ANEC contours, except for a small parcel of land affected by the limited seaward extension of the runway in 1998.

The digitised 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 ANEC contours can be easily interpolated to create a continuum of noise contours from 20 to 45 for the perceived aircraft noise affected area,

2. 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,

3. 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.

4. GIS enables modelling of the aggregate property price affect caused by aircraft noise on all properties within the affected location.

Methodology.

The data are all probable market transactions of detached and semi-detached houses within residential zoning areas that occurred within 1995 and 2000 within the study area. The resulting data were 5207 transactions in 1995 and 4265 transactions for 2000.

A standard set of property descriptors (Table 2) were used in a form that should remove major problem of multi-collinearity. ANEC levels were included using dummy variables for levels of 20-25, 25-30 and over 30. The number of observations that have ANEC levels above 20 is substantially greater in the 1995 data set than in the 2000 data set. The relevant numbers of observations are

ANEC	1995 Data	2000 Data
ANEC 20-25	180	110
ANEC 25-30	56	20
ANEC >30	23	13

In 1995 some 5% or 259 of the transactions had an ANEC over 20 while in 1995 only 3% (143) of the transactions fell into this category. This may suggest a reluctance of people to sell properties affected by aircraft influences during a period of relative uncertainly about the affect of the runway extensions. It may also impact upon the validity of the model for the year 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. These variables include an estimate of the buildings area and condition, the locational influence of the distance to the CBD shopping area as well as beachfront and nearness to beach influences and finally a set of dummy variables that categorise the building style and materials and are subject to considerable change in taste and choice. For these models relating to aircraft noise and related affects, some additional variables were added. In particularly these include the distance from the property to the airport terminal, dummy variables for ANEC levels and an average household income level for the statistical collection district that the property is located in. The model is log-linear and implied percentage effects are estimated.

Results

The Hedonic models produce results that are typical for the Adelaide housing market and with the available data. The regression coefficients are consistent with the previous studies and model statistics such as R squared and F are as expected with models that use this limited set of property characteristics. Statistically the model is 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 model all of the ANEC dummies are significantly different from 0.

Table 2 - Variables used in the Analysis

Variables	Description
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
MEDIAN_H	Average household 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
MEDTERAN	Dummy variable to record if the building has a Mediterranean style
RANCH	Dummy variable to record if the building has a Ranch style
SPANISH	Dummy variable to record if the building has a Spanish 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 ANEF reading between 20 and 25
ANEC25	Dummy variable to record if the property has an ANEF reading between 25 and 30
ANEC30	Dummy variable to record if the property has an ANEF 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

The results from the models are presented in full in Table 4 and Table 5 in Appendix 2. A simplified comparison of the 1995 and 2000 model outcomes is presented in Table 3.

Table 4 and Table 5 in the appendix, show results that are quite typical for Hedonic models of the Adelaide residential property market (Rossini, 1996,1997,1998,2000) although none of these earlier analyses incorporated ANEC zones as household characteristics. The 1995 and

2000 models estimated here are very similar with most coefficient estimates being statistically indistinguishable.

Table 3 -Comparison of results

	1995		2000	
Variable	%	Sig	%	Sig
HAREA	0.41%	*	0.46%	*
COND	6.17%	*	3.07%	*
DISTMALL	0.00%	*	0.00%	*
DISTAIR	0.00%		0.00%	
MEDIAN_H	0.03%	*	0.04%	*
TFWALL	-15.26%	*	-12.24%	*
STWALL	3.68%	*	5.89%	*
ARCHIT	8.27%	*	10.96%	*
AUSTER	-4.74%	*	-6.65%	*
BUNGALO	7.11%	*	5.28%	*
COLONIAL	6.43%	*	4.36%	*
CONTEMP	-0.96%		-1.45%	
SAHT	4.30%	*	6.22%	*
COTTAGE	-0.20%		11.64%	*
MANSION	-60.67%	*	-2.15%	
MEDTERAN	-2.59%		-1.72%	
RANCH	-5.19%	*	-5.29%	*
SPANISH	0.64%		-2.65%	
TUDOR	19.77%	*	20.29%	*
VILLA	13.67%	*	12.41%	*
GIROOF	0.64%		-1.89%	
IMTILROF	-5.73%	*	-6.87%	*
SLATEROF	41.46%	*	4.96%	
ASBROOF	2.71%		6.89%	*
ANEC20	-6.83%	*	-11.61%	*
ANEC25	-10.56%	*	-16.17%	*
ANEC30	-12.68%	*	-12.25%	*
BECHFRNT	52.17%	*	56.56%	*
CLOSBEAC	19.22%	*	19.70%	*
SEMIDET	3.30%	*	-6.21%	*

The estimates for the effect of aircraft noise show some interesting movements. In 1995 the effect is a typical pattern showing decreases in value when there is a significant ANEC. Higher ANEC levels lead to even greater decreases in value. Locations within an ANEC range of 20 to 25 show an average decrease in value of 6.8% holding all other variables constant while the effect in the 25 to 30 ANEC range is a decrease on average of 10.5%. An average decrease of 12.68% occurs when the ANEC is greater than 30.

The results for 2000 show a change in pattern. The percentage price decrease for properties exposed to noise above the 30 ANEC range remain basically the same (-12.25%). The changes have occurred in the 20-30 ANEC ranges. Expected price reductions due to the affect of aircraft noise exposure has increased in these areas with suggested percentages depreciation of 11.71% in the 20-25 ANEC range and of 16.17% in the 25-30 ANEC range.

Statistically, the differences between the 1995 and 2000 estimated impacts of airport noise upon properties in the 20-30 ANEC zones are not highly significant, the t-stats indicating 95% confidence interval ranges of around plus or minus 2%. All the same the estimates are reasonably well determined and this raises the question as to why these changes are likely to have occurred. There are a number of possible explanations.

First, householder perceptions of noise exposure within the 20-30 ANEC zone may have changed, even though actually exposure has not. There is at least one reason why this might have happened. In late 1999 an agreement was reached that households subject to high levels of noise exposure should be provided with noise abatement features, even though the actual number of complaints received from these households regarding noise was minimal. An interesting consequence of this legislation was that households marginally less exposed now did complain and demand similar compensatory measures. A second explanation is that in 2000, households incur greater disutility for a given level of noise exposure compared to 1995. This possibility is of interest in that it is somewhat counter-intuitive, since householders might have been assumed to grow more accustomed to airport noise and therefore incur less disutility for a given level of noise exposure.

A third possibility is that the measurement of noise exposure, and hence the ANEC contours used in this study, are incorrectly determined. This is not as unlikely as it may seem as there have been instances in the past where the incorrect mix of aircraft has been used in ANEF/ANEC computations. A fourth and related explanation, following Levesque, is that the use of a single composite noise exposure index is inappropriate. Recognising that different dimensions of noise exposure such as intensity, frequency, duration and predictability do have specific and different impacts on households, the use of a single composite measure is in effect assuming that the 'weights' in the index have remained constant. We know for certain that intensity has reduced but that frequency has increased.

Whatever explanation, or combination of explanations is correct, one outcome of the research so far appears relatively clear cut. The impact upon the residential house prices in the locations defined by the 20-30 ANEC zones used in the study appears to be substantially greater in 2000 than in 1995, or than in the earlier Burns et al 1989 study. It is of interest that a similar effect has not been identified among residential properties subject to higher levels of noise exposure but there are several possible contributors to this particular result. The actual number of properties and of recorded sales in 30+ ANEC zones is relatively small and it is these properties that have recently been furnished with noise abatement features.

Leaving the latter matter aside, if we consider in Table 1 again the magnitudes of the key components that determined the location of Adelaide Airport, it is quite clear that even the possible doubling of the noise exposure impact would have minimal impact upon the overall cost-benefit analysis outcome. The airport is appropriately located and will continue in the foreseeable future to provide a useful test bed for research into the impacts of airport noise and exposure upon residential property values.

Concluding Remarks.

It has been made clear throughout this paper that this is 'research in progress' and that only limited exploratory results have so far been obtained. Notwithstanding this cautionary comment we believe that the paper does illustrate the power and potential of the use of Geographic Information Systems technology, especially with regard to the merging of geographic and textural data and in the management of the large data sets inherent in this kind of research. There are, however, a number of areas where further attention is required. At the general level, the whole issue of variable selection and statistical testing remains a major issue in Hedonic analysis. At the more specific level, there are a number of directions research into the impacts of noise exposure from Adelaide Airport can take with a view to obtaining greater confidence in the results. These directions include the use of individually determined ANEC maps for each year, something that given the availability of house sales data would enable a genuine dynamic Hedonic modelling exercise to be undertaken. Such an approach would also offer more insight into whether the introduction of compensatory noise abatement measures for specific households actually stimulated greater community awareness of and reaction to noise exposure. Finally, the results obtained may be seen to be more robust if confirmed through alternative empirical approaches, such as choice-based conjoint analysis and artificial neural network modelling.

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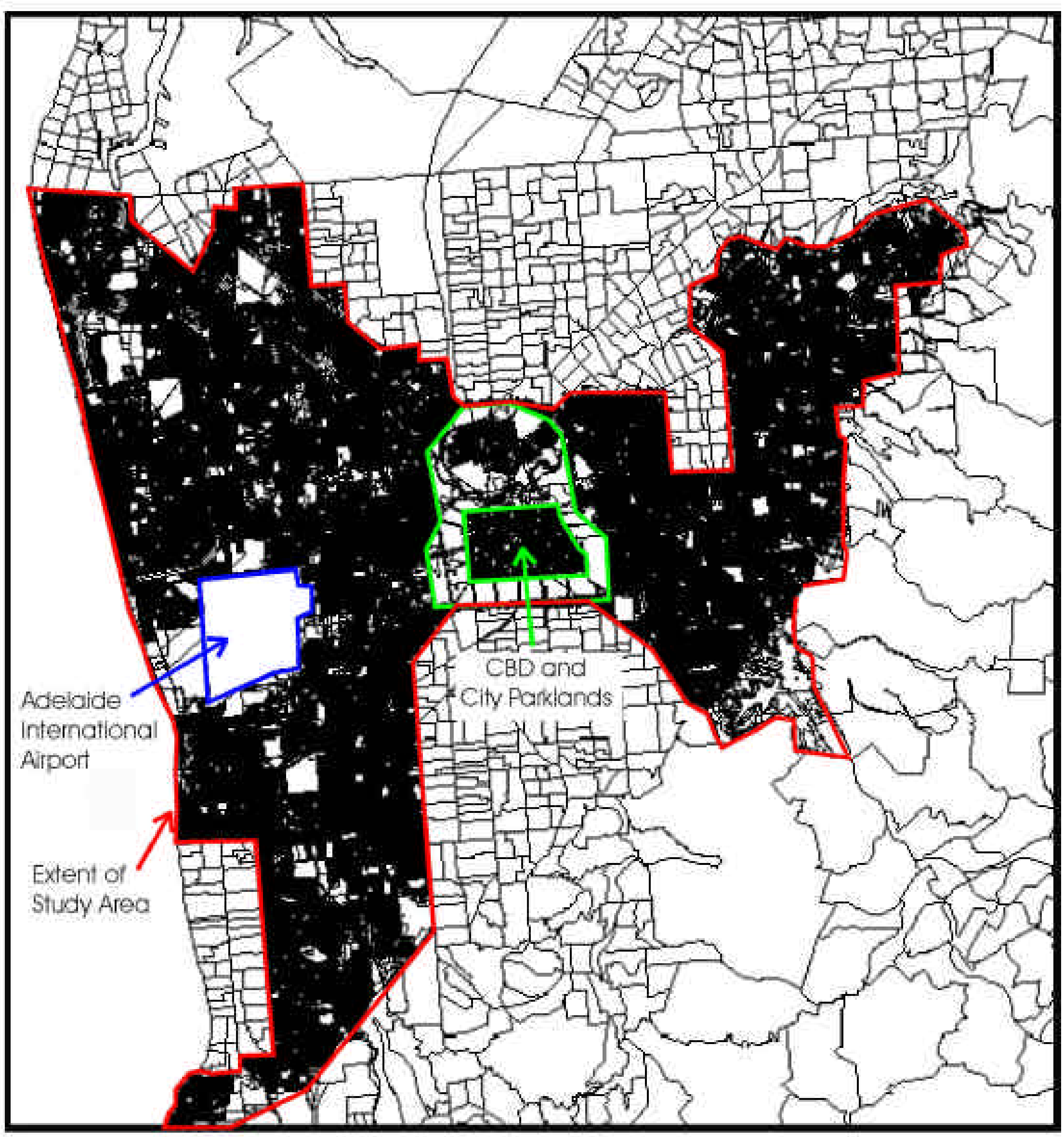
Appendix 1

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



Appendix 1, continued

Figure 2 - Adelaide Airport – ANEC Contours, 1998

Appendix 2

Table 4 - Model Summary Using 1995 Sales

R Square	0.7106
Adjusted R Square	0.7089
Std. Error of the Estimate	0.2114

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	568.0042	30	18.9335	423.7778	0
Residual	231.2971	5177	0.0447		
Total	799.3013	5207			

Dependent Variable: LNPRICE

Variable	B	Std. Error	t	Sig.	VIF	Equation	% Effect	95% Sig
(Constant)	10.8629	0.0242	448.5077	0.0000		52201.59		
HAREA	0.0041	0.0001	62.9047	0.0000	1.5343	1.0041	0.41%	*
COND	0.0598	0.0032	18.9062	0.0000	1.4920	1.0617	6.17%	*
DISTMALL	0.0000	0.0000	-30.7852	0.0000	2.2766	1.0000	0.00%	*
DISTAIR	0.0000	0.0000	1.8368	0.0663	1.7363	1.0000	0.00%	
MEDIAN_H	0.0003	0.0000	18.3637	0.0000	1.4518	1.0003	0.03%	*
TFWALL	-0.1655	0.0182	-9.0880	0.0000	1.2352	0.8474	-15.26%	*
STWALL	0.0361	0.0088	4.0897	0.0000	1.2041	1.0368	3.68%	*
ARCHIT	0.0795	0.0302	2.6304	0.0086	1.1126	1.0827	8.27%	*
AUSTER	-0.0486	0.0132	-3.6904	0.0002	1.2153	0.9526	-4.74%	*
BUNGALO	0.0686	0.0123	5.5923	0.0000	1.8345	1.0711	7.11%	*
COLONIAL	0.0624	0.0133	4.6793	0.0000	1.1415	1.0643	6.43%	*
CONTEMP	-0.0096	0.0167	-0.5749	0.5654	1.2115	0.9904	-0.96%	
SAHT	0.0421	0.0159	2.6532	0.0080	1.2235	1.0430	4.30%	*
COTTAGE	-0.0020	0.0151	-0.1305	0.8961	1.6567	0.9980	-0.20%	
MANSION	-0.9332	0.1098	-8.5012	0.0000	1.3474	0.3933	-60.67%	*
MEDTERAN	-0.0263	0.0614	-0.4282	0.6685	1.0096	0.9741	-2.59%	
RANCH	-0.0533	0.0225	-2.3717	0.0177	1.0332	0.9481	-5.19%	*
SPANISH	0.0063	0.0273	0.2321	0.8165	1.0247	1.0064	0.64%	
TUDOR	0.1804	0.0229	7.8927	0.0000	1.0904	1.1977	19.77%	*
VILLA	0.1281	0.0144	8.9113	0.0000	1.6606	1.1367	13.67%	*
GIROOF	0.0064	0.0094	0.6834	0.4944	2.1679	1.0064	0.64%	
IMTILROF	-0.0590	0.0140	-4.2074	0.0000	1.4181	0.9427	-5.73%	*
SLATEROF	0.3469	0.0936	3.7049	0.0002	1.1759	1.4146	41.46%	*
ASBROOF	0.0267	0.0224	1.1935	0.2327	1.1223	1.0271	2.71%	
ANEC20	-0.0708	0.0168	-4.2200	0.0000	1.0708	0.9317	-6.83%	*
ANEC25	-0.1116	0.0288	-3.8742	0.0001	1.0286	0.8944	-10.56%	*
ANEC30	-0.1356	0.0436	-3.1112	0.0019	1.0154	0.8732	-12.68%	*
BECHFRNT	0.4198	0.0411	10.2134	0.0000	1.0532	1.5217	52.17%	*
CLOSBEAC	0.1758	0.0093	18.9152	0.0000	1.6052	1.1922	19.22%	*
SEMIDET	0.0325	0.0116	2.7914	0.0053	1.2471	1.0330	3.30%	*

Appendix 2, continued

Table 5 - Model Summary Using 2000 Sales

R Square	0.7489
Adjusted R Square	0.7471
Std. Error of the Estimate	0.2109

ANOVA

	SS's	df	Mean Square	F	Sig.
Regression	561.9481	30	18.7316	420.9674	0
Residual	188.4430	4235	0.0445		
Total	750.3911	4265			

Dependent Variable: LNPRICE

Variable	B	Std. Error	t	Sig.	VIF	Equation	% Effect	95% Sig
(Constant)	11.2581	0.0261	430.6311	0.0000		77502.88		
HAREA	0.0046	0.0001	59.9658	0.0000	1.5328	1.0046	0.46%	*
COND	0.0302	0.0037	8.1991	0.0000	1.5791	1.0307	3.07%	*
DISTMALL	0.0000	0.0000	-37.0646	0.0000	2.2545	1.0000	0.00%	*
DISTAIR	0.0000	0.0000	-0.3380	0.7354	1.6715	1.0000	0.00%	
MEDIAN_H	0.0004	0.0000	22.7258	0.0000	1.5054	1.0004	0.04%	*
TFWALL	-0.1306	0.0172	-7.5813	0.0000	1.2291	0.8776	-12.24%	*
STWALL	0.0572	0.0254	2.2533	0.0243	1.1525	1.0589	5.89%	*
ARCHIT	0.1040	0.0305	3.4048	0.0007	1.1579	1.1096	10.96%	*
AUSTER	-0.0688	0.0141	-4.8960	0.0000	1.1963	0.9335	-6.65%	*
BUNGALO	0.0515	0.0143	3.5865	0.0003	1.8912	1.0528	5.28%	*
COLONIAL	0.0427	0.0153	2.7951	0.0052	1.1260	1.0436	4.36%	*
CONTEMP	-0.0146	0.0181	-0.8076	0.4194	1.1772	0.9855	-1.45%	
SAHT	0.0604	0.0153	3.9420	0.0001	1.1898	1.0622	6.22%	*
COTTAGE	0.1101	0.0196	5.6255	0.0000	1.4438	1.1164	11.64%	*
MANSION	-0.0217	0.1299	-0.1672	0.8672	1.1367	0.9785	-2.15%	
MEDTERAN	-0.0173	0.0489	-0.3541	0.7233	1.0181	0.9828	-1.72%	
RANCH	-0.0544	0.0233	-2.3375	0.0195	1.0367	0.9471	-5.29%	*
SPANISH	-0.0268	0.0366	-0.7334	0.4633	1.0157	0.9735	-2.65%	
TUDOR	0.1847	0.0292	6.3328	0.0000	1.0569	1.2029	20.29%	*
VILLA	0.1170	0.0176	6.6554	0.0000	1.4422	1.1241	12.41%	*
GIROOF	-0.0191	0.0106	-1.8069	0.0708	2.0395	0.9811	-1.89%	
IMTILROF	-0.0712	0.0163	-4.3663	0.0000	1.4376	0.9313	-6.87%	*
SLATEROF	0.0484	0.0658	0.7352	0.4622	1.1659	1.0496	4.96%	
ASBROOF	0.0666	0.0237	2.8091	0.0050	1.0899	1.0689	6.89%	*
ANEC20	-0.1234	0.0212	-5.8220	0.0000	1.0820	0.8839	-11.61%	*
ANEC25	-0.1763	0.0476	-3.7029	0.0002	1.0146	0.8383	-16.17%	*
ANEC30	-0.1307	0.0571	-2.2904	0.0220	1.0207	0.8775	-12.25%	*
BECHFRNT	0.4483	0.0716	6.2593	0.0000	1.0352	1.5656	56.56%	*
CLOSBEAC	0.1799	0.0129	13.9053	0.0000	1.3873	1.1970	19.70%	*
SEMIDET	-0.0641	0.0144	-4.4633	0.0000	1.2461	0.9379	-6.21%	*