Estimating the capitalised value of underground power in Perth

A report prepared for the Economic Regulation Authority

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1 Introduction

1.1 Background

As part of the *Inquiry into the costs and benefits of the state underground power program* (the Inquiry), the Economic Regulation Authority (ERA) has sought to quantify the amenity value of underground electricity distribution connections to residential property owners in the Perth metropolitan area. There exists no competitive market from which the value of underground power to households can be observed. However, the additional amenity value associated with the removal of overhead distribution assets is expected to be capitalised within the sale price of a residential property, which is directly observable at the time of sale.

The ERA has therefore concluded that a hedonic model of the Perth residential property market can be utilised to determine the marginal value of underground power to Perth residential property owners. The value of underground power at a household level can then be interpolated back to those households involved in the State Underground Power Program (SUPP), to form an estimate of the private benefits to households from the SUPP.

1.2 Approach

The ERA has asked Marsden Jacob Associates' (MJA) to undertake a hedonic analysis to determine the capitalised value of underground power in the Perth residential property market. MJA has developed a methodology that allows for the estimation of the marginal value of underground power utilising a range of standard and novel data sources.

The key components of this approach include:

- a tool for importing and validating LandGate property sales data;
- appropriate mapping software to incorporate geographical characteristics into the statistical analysis; and
- the statistical module required for regression analysis of data from the two aforementioned sources.

MJA's objective is to form a household-level estimate of the value of underground power in the Perth metropolitan area. The estimate was to be based on all households that have underground power (not only those involved in the SUPP), and take account of changes in the implicit value of underground power both over time and on a cross-sectional basis. This document outlines the data collection and processing processes, and statistical techniques used by MJA to meet the aforementioned objective.

1.3   Results

Based on the hedonic model and data sources outlined in this document, MJA has concluded that the mean implicit value of underground power in the Perth metropolitan area is $9,962 (real, 2011), or an average of 1.6 per cent of the residential property (house) price. However, caution should be exercised when utilising the mean value, as the capitalised amenity value of underground power is itself an endogenous function of other housing attributes. Such attributes include the location, property age and potential for views from the property.

2   Data Sources

2.1   Property Sales Data

LandGate maintains a database of all property sales within Western Australia. In addition to transaction related details, the database includes a number of additional variables detailing the characteristics of the property. For example, variables include the transaction date and value, property location, and the land area on which the property is based. The range of attributes included in the database differs depending on whether the property is classed as commercial or residential. Residential properties are then further disaggregated on the basis of whether the property is a stand-alone house, duplex, or apartment.

The ERA purchased a non-commercial license to utilise the LandGate property sales database, and MJA was provided with temporary access to the database on a confidential basis, in order to develop the appropriate tools, and for estimating the relevant parameters for the hedonic model.

2.2   Data relevant to SUPP

A table containing details of all relevant SUPP sites to date was compiled by Western Power and provided to the ERA. The table provided project-level statistics for various sites. The table included:

- project Name;
- commencement and completion date;
- project costs;
- connections; and
- length of underground assets installed.

Western Power also provided the ERA with a spreadsheet listing those properties involved in the SUPP. Properties were listed by Property Identification Number (PIN) along with the relevant SUPP sub-project name.

2.3   Property location information

Property location has a significant influence on property value. Tapsuwan (2009) notes the significant affect of each suburb on property values. However, information obtained from a higher level of spatial resolution may be a more reliable predictor of property value. It was therefore necessary to be able to identify the location of a property and nearby characteristics. A number of online tools readily provide the necessary information in a geographic information system (GIS) based format.

GIS-based information used in this project included:
- LandGate Shared Land Information Platform (SLIP) database;
- OpenStreetMap (OSM) SQL database; and
- Google maps.

In order to access the aforementioned online GIS tools, it was necessary for MJA to develop functional interfaces between each online source and the ERA's copy of the LandCorp property sales database. The interface is described in the following section.

3 Data processing methodology

3.1 Model development

The interface referred to in section 2.3 was constructed in the R statistical software, and includes the use of a range of packages including:

- Maptools;
- PBSMapping;
- RSQLite;
- Raster; and
- lmTest for testing linear regression models.

Further information on the R software package can be found at http://www.r-project.org.

3.2 Construction of property characteristics database

LandGate provided the ERA with approximately 350 spreadsheet files containing property transactions in Western Australia for the period 2000 to 2010. Each data file contained information on 59 different variables relating to transactions occurring within a quarter. Approximately 2,500 transactions were contained in each file, therefore requiring up to six data files to account for all transactions within the quarter. In order to proceed with any analysis of the LandGate sales data, it was necessary to aggregate all of the data files into a single database.

The software developed by MJA automatically filtered and aggregated all relevant input data files into a single database. The relevant filtering included:

- the removal of twenty variables, on the basis that they were not required in any further analysis;
- entries where a single trade was recorded multiple times;
- further data quality checks to ensure the completeness of each data entry (no missing data); and
- all properties not defined as a residential house were excluded.

A total of 786,228 properties remained in the data set following filtering.

3.3   GIS-based data analysis

3.3.1   Property location

The first stage of the GIS component was to accurately identify and record the geographical coordinates for each property contained within the LandGate property database. MJA made use of the Google Maps Geocoding function to identify the properties location, reporting precise latitude and longitude coordinates.

Repeat sales of a single property within the database were identified to reduce data processing times. This approach allowed a single geocode query to apply to multiple sales entries in the database.

### 3.3.2   Filtering based on location

MJA was required only to examine properties within the Perth metropolitan region. Properties outside a specific boundary box could therefore be excluded from further analysis.

A boundary box was selected which would capture SUPP retrofit sites, an appropriate sample of green fields development and a sample of suburbs with non-underground distribution assets. The coordinates of the boundary box were:

- North-west corner: -31.575,115.630; and
- South-east corner: -32.347,116.204

The location of the boundary box is illustrated in figure 1 below.

Figure 1: Perth Metropolitan region within the boundary box

Source: http://www.openstreetmap.org
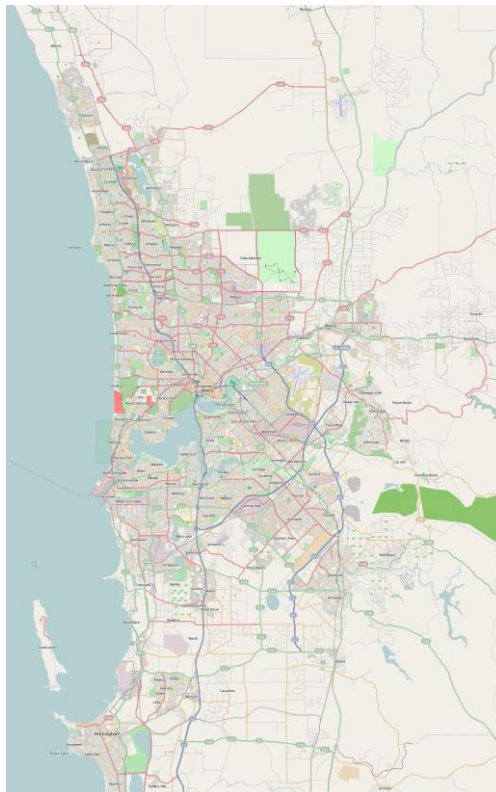
3.3.3 Geographic feature set

Neighbourhood attributes have a direct impact on property prices, and may also have an affect on the value of underground power to households. Relevant attributes considered within this model include nearby road types (for example, freeways, dual carriage and main roads), water features (beaches rivers, lakes and the ocean), parks and public open space. It is possible to expand the list of attributes to include other made-made characteristics, such as public transport networks, shopping centres, and entertainment precincts.

In order to determine the geographical attributes of an area, OSM map tiles were downloaded for the geographical area illustrated in figure 1 and subsequently converted into raster format within R. Each tile represented an area of approximately 200 meters by 200 meters. The neighbourhood-level attributes on each map tile could thus be extracted onto a mosaic of tiles, for the Perth metropolitan region.

While it is possible to achieve a significantly higher level of spatial resolution, such detail was not considered to be appropriate for this project. The additional resolution would likely result in a significant increase to model processing times with only a marginal benefit to the effectiveness of the hedonic model.

3.3.4 Neighbourhood characteristics

Based on the raster mosaic produced in the previous section, a bounded subset region of approximately five kilometres squared was extracted surrounding each property. The choice of area was based on a multiple of the OSM map tiles. The subset region could then be examined in isolation, deriving an estimate of the physical features. For each property, a standard measure for each of the attributes listed in section 4.3.3 was stored, in addition to the existing LandGate sales data.

3.4 Defining the underground power data set

3.4.1 Overview

While Western Power provided a list of all properties that have received underground power via the SUPP, involvement in the SUPP is neither a necessary nor sufficient condition for a property to have an underground electricity distribution connection. As Western Power was unable to provide further information for the type of connection utilised by non-SUPP households, it was necessary to define an approach to classifying whether a property received overhead or underground power through a proxy variable.

Following discussions with the ERA, it was determined that, in additional to SUPP retrofitted properties, two distinct types of properties would utilise underground power. They are properties constructed in:

- green-field suburbs post-1995; and
- brown-field redevelopments post-1995.

In most circumstances, suburbs developed after 1995 had underground power installed, rather than overhead power as a result of government policy.

It is necessary to correctly determine whether or not a property has underground power in order for the hedonic model to accurately quantity the value of underground power to households.

3.4.2 Green-field developments

In order to determine whether a suburb should be classified as a post-1995 green-field development, the distribution of property construction dates in each unique suburb was examined. If the earliest construction date for properties constructed a suburb was after 1995, then it can be assumed that the suburb has underground power.

However, as can be seen for the suburb of Success in figure 2, utilising the minimum construction date may not be representative of the sample. Therefore, the 10th percentile of the distribution of construction dates was used rather than the earliest date to determine whether the suburb should be classified as a post-1995 green-fields development.

**Figure 2: Property construction dates in Wembley and Success**
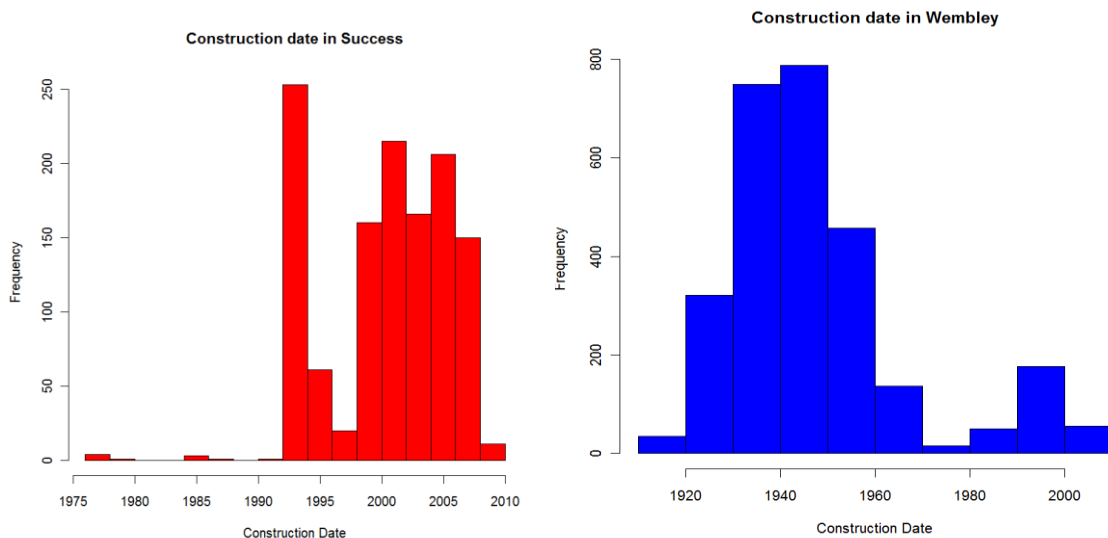
Source: LandGate database and MJA analysis

Consequently, it is assumed that if the 10th percentile of the build date of properties within a suburb is later than 1995, then all properties within that suburb have underground power.

3.4.3 Brown-field developments

Some redevelopments have resulted in the delivery of underground power to parts of a suburb when the wider suburb does not have underground power. For example, the development of a site on the corner of Aberdare Road and Smyth Road in Shenton Park has delivered underground power to a part of a suburb, which otherwise has limited overhead power supply assets in place. As is illustrated in figure 3, overhead assets are still in place for surrounding streets, while the redevelopment in question was constructed with underground power in place, as required by current government policy.

Figure 3: Shenton Park redevelopment site
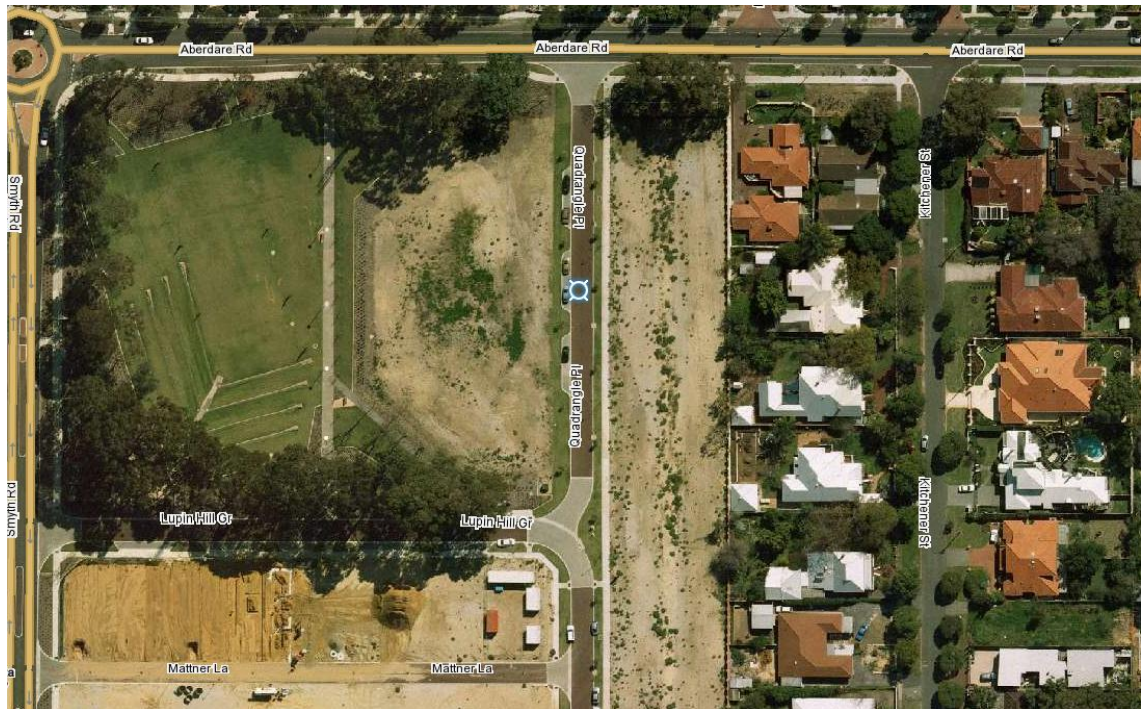
Source: Whereis/Sensis (http://www.whereis.com)

As agreed with the ERA, MJA determined the distribution of property construction dates for every unique street in the Perth metropolitan area. Similar to the green-fields solution, if the 10th percentile construction year of the street was later than 1995, then the street was classed as a brown-field development utilising underground power.

This may result in properties being incorrectly identified as having underground power in circumstances where:
- only properties constructed post-1995 have sold in a street otherwise containing older properties (the sample of properties sold is not representative of the population); and
- sections of streets were subject to redevelopment without the entire street being redeveloped.

In order to ascertain the validity of the method, a sample of properties was selected for visual inspection. The random sample consisted of 56 properties from the group identified as brown-field redevelopments. In total, one property from the sample was incorrectly identified as having underground power, resulting in an error rate of 1.79 per cent. While further sampling is desirable, it is considered unlikely that there exists a systematic error within the underground/overhead assignment methodology.

3.5   Identification of outliers

The LandGate property sales data contain a number of properties with a set of characteristics which differ significantly from the mean set of characteristics. In order to ensure that the results of the hedonic model are not driven by a limited number of extreme points, a filtering function was introduced to remove potential outliers.

Examples of properties identified as outliers include:

- a house with 18 carports;

- nine houses with less than three rooms; and

- properties with sale values less than $1,000.

MJA has no additional information to suggest that any data have been incorrectly recorded, or that the data do not accurately portray the property in question. Nevertheless, the potential for the results to be driven by a limited number critical data points remains high. As such points were not representative of the underlying distribution of property characteristics, they were removed.

The filtering function worked on both a suburban and whole-of-sample level. The relevant conditions included in the final version of the model excluded properties that had:

- fewer than four rooms, or greater than 18 rooms (see figure 4);

- fewer than one bedroom;

- a build date later than 2011, or before 1930;

- a block size greater than 2.5 standard deviations above the suburb average;

- a price greater than $2,000,000 or less than $100,000; and

- properties with a traded value in the top and bottom 2.5 per cent for relevant suburb.

Figure 4: Distribution of room numbers in sample
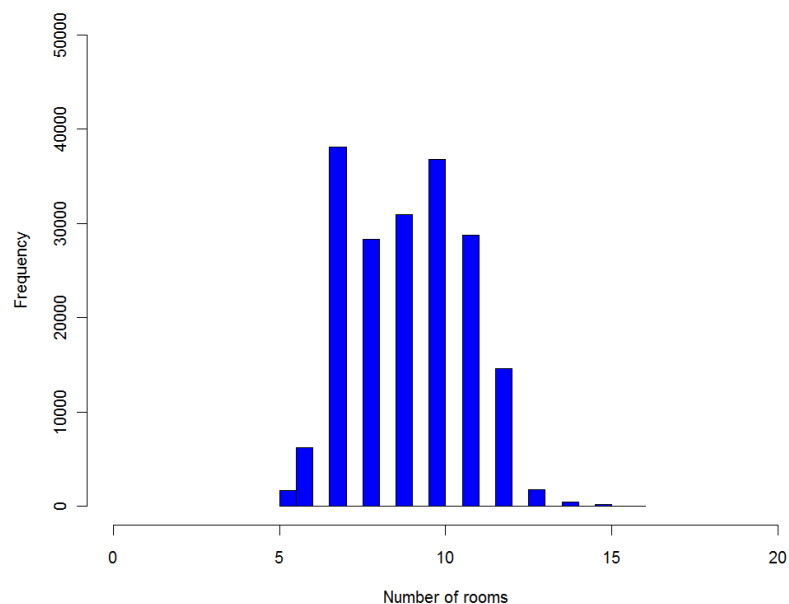
Source: LandGate database and MJA analysis

All properties in suburbs with fewer than 100 trades over the sample period (2000 to 2010 were removed. It was anticipated that small sample sizes would result in statistically insignificant results, as a suburb-level variable was included in the hedonic model. Furthermore, there is an increasing likelihood that the small sample may not be representative of the wider population.

3.6 Tertiary processing of data

A number of additional variables were derived from the LandGate data which were incorporated into the hedonic model. Derived variables included the age of the property at the time of sale and whether the property was a new built at the time of sale. Figure 5 illustrates the distribution underlying the property age variable, utilising a restricted data sample.

Sale prices were also adjusted by the Consumer Price Index[1] for Perth, so that all prices were in real terms for the first quarter of 2011.

Figure 5: Distribution of property age at time of sale, 2000-2010
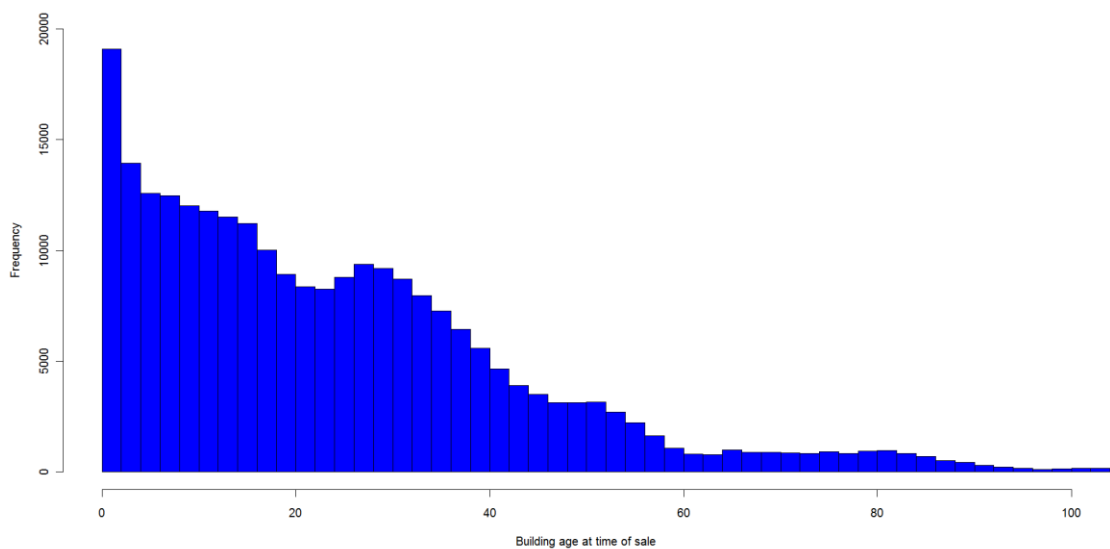
Source: LandGate database and MJA analysis

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[1] Australian Bureau of Statistics Catalogue 6401.0; All Groups (Perth).

4   Hedonic Model Specification

4.1   Overview

The hedonic pricing method is a technique for estimating the (implicit) value of the characteristics that differentiate closely related products (Freeman, 2003, p.356). Real estate can be thought of as a heterogeneous product, comprising of numerous individual attributes. The price paid by a consumer in a competitive market for a residential property will therefore be a function of the endowment of attributes embodied by the property in question. Consequently, when correctly specified, the hedonic approach can be used to estimate the capitalized amenity value associated with the removal of overhead electricity distribution assets.

4.2   Prior research

Many previous studies have utilised hedonic pricing methods to determine the implicit of housing attributes. The context of prior research has been highly varied; from examining the implicit value of access to coastline, to determining the marginal value of improved air quality. However, the number of studies utilising the hedonic pricing approach to property in Western Australia is limited. Previous research includes McLeod (1984), Barnett (1985), Tapsuwan et al (2009) and Jones (2010).

From the aforementioned sources, only Barnett (1985) included underground power as an exogenous variable within the model. Barnett (1985) concluded that the marginal value of underground power to residents was -$813.44, and explains the negative value of the coefficient in the context of high installation costs of underground power at that point in time.

4.3   Model specification

The model specification follows that of Hansen (2009), in adopting a general form of:

$$P_{i,t} = \sum_{T=1}^{T} D1_{i,t}\alpha_t + X_{i,t}\beta + \varepsilon_{i,t}$$

Where:

- $P_{i,t}$ is the log of the price of house i when sold at time t;
- $D1_{i,t}$ is a vector of dummy variables with a value of one if the house sold in time t and zero otherwise;
- $X_{i,t}$ is a vector of house characteristics for house i when sold at time t; and
- $\varepsilon_{i,t}$ is a white noise term.

The rationale for including a time dependent term was the significant increase in Perth residential property prices between 2003 and 2007, as illustrated in figure 6. By decompiling parameters both a time and variable-dependent component, it should be possible to determine whether any amenity value associated with underground power has increased or decreased over time.

Figure 6: Residential Property Price Growth in Perth, 2000-2010
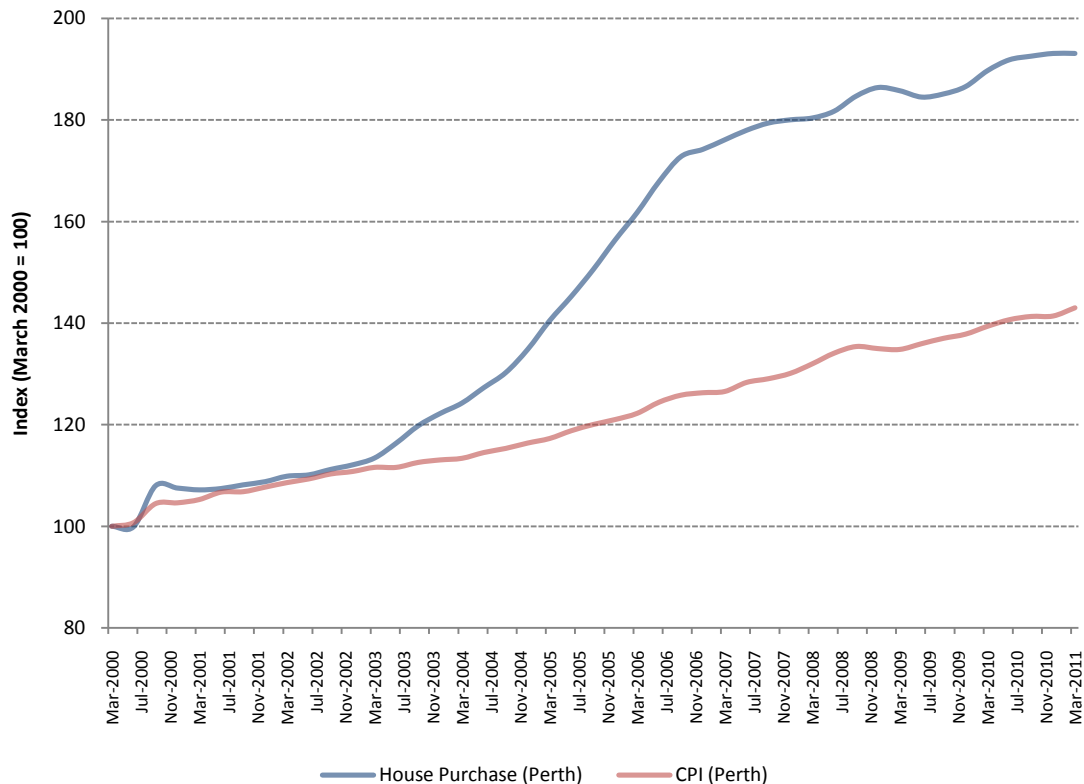
Source: ABS Catalogue 6401.0 (Perth CPI) and 6401.9 (Perth House Purchase)

Criticisms in the literature of Rosen's (1974) hedonic pricing approach have been recognised when undertaking this project. It is argued that Rosen's (1974) method of identifying technology may result in biased model specification (for example, see Parsons, 1986, p.347). Similarly, Ekeland et al (2004) considered whether equilibrium in hedonic markets imposes restrictions on estimating the functional form of demand in the market. Ekeland et al (2004) notes that when a market is in equilibrium, the correct underlying specification may not be linear. This leads to a secondary set of challenges regarding nonlinear model specification.

The limitations presented by the aforementioned issues have been acknowledged. As the ERA has sought an implicit price for underground power, as opposed to a fully-specified demand function, the current methodology is believed to be appropriate. Responding to the criticisms of Rosen's (1974) approach were considered outside the scope of this project, and would not have been possible given the constraints on project timing. However, it remains possible to incorporate an additional mechanism (such as that employed by Parsons) into the existing analytical framework.

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4.4 Variables

4.4.1 Rationale for variable inclusion

As has been discussed, there exist a large number of variables that could be incorporated within the hedonic model. There are many attributes associated with a house. Correctly specification of the hedonic model requires a prima facie understanding of consumer's utility function. For the purposes of constructing the hedonic model of housing in Perth, MJA has relied on a range of sources, including Tapsuwan (2009), Freeman (2003) and Parsons (1986).

4.4.2 Variables considered

Variables used within the final form of the model included:

- relative property age at time of sale (defined as the year of sale minus the year of construction);
- distance from the coast;
- distance from Perth CBD;
- number of rooms;
- existence of underground power connected to the property;
- land area as a function of the suburb suburb; and
- relative distance to attributes such as a beach, river or ocean.

The time index, as defined in section 4.3, can be utilised on either a quarterly or annual basis.

The variables were incorporated on the basis of their use in prior literature on hedonic pricing. The difficulty in accurately specifying the relationship between the attributes of a property and the property sale price is noted. While there does not exist a formal consensus on the appropriate variables to consider, the variables used within this model have been incorporated extensively by previous authors.

4.4.3 Exclusion of variables

A number of variables were excluded from the hedonic model on the basis of statistical insignificance. For example, the ratio of private-property to public open space in the neighbourhood surrounding a property was not statistically significant in any form of the model.

4.4.4 Collinearity

In an early form of the model, a range of GIS related variables were independently included in the model. However, examination of a correlation matrix and visual inspection of scatter-plot diagrams illustrated the significant degree of covariance between some variables. For example, the physical relationship between the ocean and beach resulted in a high degree of collinearity between the two relevant variables.

When collinearity was identified, the relevant variables were collapsed into a single variable. Such variables included the previous beach and ocean example, and the number of rooms and number of bedrooms.

4.4.5 Heteroscedasticity

Application of the Breusch-Pagan test identified the presence of statistically significant[2] heteroscedasticity within the hedonic model. A number of unsuccessful attempts were made to reduce the heteroscedasticity through modification of the functional form of variables. Consequently, robust standard errors were used rather than attempting any significant change to the functional form of the hedonic model.

4.5 Out-of-sample forecast

A random sample of data points was extracted in order to undertake an out-of-sample forecast, as a means of determining the validity of the proposed functional form. The sample sizes consisted of 5 and 10 per cent of the total data set. As the sampling process was random, the out-of-sample set was not weighted towards a particular time period (for example, for examining how well the model would forecast sales prices in 2010 based on a 2000-2009 input set) or single region of Perth.

The Mean Squared Error (MSE) of two different hedonic model specifications was compared using the out-of-sample data set. The first specification used the variables discussed in section 4.4.2, and was compared with the simpler hedonic specification utilised in Parsons[3] (1986). The MSE of the proposed specification was significantly lower, indicating that the inclusion of the GIS-related and other variables contributed towards the reliability of the proposed hedonic model.

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[2] At the five per cent level.

[3] Parsons (1986) was able to use a measure of property quality which was not available in the LandGate data set. Consequently, building age was used as an alternate.

5   Results and conclusion

5.1   Results

5.1.1   Overview

In addition to estimating the mean value of underground power to households in Perth, the ERA requested that the hedonic model be applied to a number of property sub-samples to isolate specific effects. For example, whether the implicit value of underground power is dependent on property location. In doing so, it is recognised that the capitalised amenity value of underground power is unlikely to be homogenous across all households. Consequently, whether the value of underground power differed as a function of property value was also considered.

5.1.2   Inter-temporal whole-of-sample result

The following section outlines the outcomes of MJA's analysis. The results contained in table 1 are considered to be a robust estimate of the capitalised amenity value of underground power in the Perth metropolitan area. The data set used to produce the results contained in table 1:

- was based on a whole-of-sample (all suburbs); and
- was undertaken on a quarterly basis.

Six of the forty periods (15 per cent) produced a statistically insignificant result. These results have been excluded from table 1. Sales data paucity is believed to be the key determinant of this outcome. A movement from quarterly to annual periods reduces the number of statistically insignificant periods to zero.

The observed range of results is primarily a function of the non-uniform pattern of sales observed over time. A proportionally higher number of trades in high-value suburbs resulted in an increased mean value of underground power (see section 5.2.2 for a discussion of this effect) in some periods.

Table 1: Estimated implicit value for underground power

Variable	Value ($, real)
Minimum	$6,214
Mean	$9,962
Standard Deviation	$2,613
Maximum	$14,069

Implicit price estimates contained in table 1 were statistically significant at the 5% level.

5.1.3   Variation by house price

A secondary problem under consideration is whether the capitalised value of underground power is correlated with the sale price of a house. By restricting the sample under consideration, an estimate of the value of underground power within four price brackets was formed. The results of the second stage analysis are included in table 2.

Table 2: Estimated implicit value for underground power

House Value ($, real)	Mean Value	% of mean sale price	% of properties in the price range
$0 - $299,999	Statistically Insignificant[4]	0%	35.2%
$300,000 - $499,999	$4,840*	1.2%	43.5%
$500,000 - $699,999	$14,210**	2.4%	15.2%
$700,000+	$29,590**	3.5%	6.1%
* Statistically significant at 10% level			
** Statistically significant at 5% level			

The results in table 2 indicate a positive relationship between the capitalised amenity value of underground power and the sale price of a property. There exist a number of possible causes for such a relationship. Higher sale prices are likely to be related to the presence of positive physical attributes, such as a view over landscape or proximity to the coast. Such physical attributes will result in a higher property values. In such circumstances, the removal of overhead power distribution assets is likely to have a significantly larger positive effect on the amenity of the property compared with a property with none of the aforementioned positive attributes.

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[4] Houses sold within the sub-$300,000 price bracket were predominantly green-field developments. As previously noted, undergroud power was mandated on green-fields development sites. Consequently, the lack of green-field sales within the price bracket that did not have underground power was small. An appropriate interpretation is therefore that the value of underground power to such households using the current methodology is not applicable, as opposed to being equal to zero.

5.2   Spatial and inter-temporal autocorrelation

It is likely that property sale prices are, in part, determined by spatially and temporally related property sales (Tapsuwan, 2009). With the availability of high-resolution GIS data, it is possible to incorporate a spatial/temporal autocorrelation function, wherein the sale price of a property is determined (at least in part) by other geographically close properties that were sold in the recent past. Such a mechanism would be resource intensive to implement, and it remains uncertain as to whether such a feature would deliver a more accurate model specification.

5.3   Conclusion

This study demonstrates the existence of a positive amenity value associated with underground power. The hedonic model previously outlined appropriately identifies the functional demand for housing in the Perth Metropolitan region. Regardless of whether underground power is retrofitted, or installed in a green-field location, underground power appears to increase the value of a residential property by, on average, 1.6 per cent.

However, care should be taken when extrapolating the results to a large sample of households. The results indicate that the exact value of underground power will co-vary according to a range of exogenous attributes. Attributes will include property location, distance from the coast and time.

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