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A Hedonic Pricing Approach to Value Ecosystem Services Provided by Water Sensitive Urban Design:

Comparison of Geelong, Australia and Singapore

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ABSTRACT

Water Sensitive Urban Design (WSUD) features are increasingly used for urban water management, green urban design, and improved community liveability, but relatively less data are available on the ecosystem services that WSUD provides. We used hedonic pricing, supported by qualitative surveys, in Geelong, Australia and Singapore, to evaluate benefits related to large WSUD features. For both locations there was a significant ($\alpha=0.05$) inverse relationship between the sales price of a residence and distance to the WSUD features. Qualitative surveys corroborated the hedonic pricing analysis, as a majority of people appreciated benefits accrued from living near WSUD features.

Keywords: *hedonic pricing; ecosystem services; WSUD; urban liveability; urban green design*

INTRODUCTION

Water Sensitive Urban Design (WSUD), also known as Low Impact Development (LID), Sustainable Urban Drainage Systems (SUDS), or Sponge Cities, is traditionally considered a decentralized, microscale design approach to stormwater management that includes some combination of features such as raingardens, grassed swales, green roofs, permeable pavement, constructed wetlands, and tree preservation. The intent here is to mimic natural hydrologic processes by re-connecting the urban surface to the underlying soil, which facilitates infiltration and storage. In fact, WSUD represents a potential dual benefit of reducing localized flooding and improving runoff quality (through filtration and adsorption). WSUD has increasingly received attention throughout the world (Selbig & Balster, 2010; Carson et al., 2013; Irvine et al., 2014; Fletcher et al., 2015; Lim & Lu, 2016; Kok et al., 2016; Yau et al., 2017; Li et al., 2017; Liu et al., 2017a; Jiang et al., 2018), but adaptation has been variable regionally and even within countries themselves (Marsalek & Schreier, 2009; Morison & Brown, 2011; Torgersen et al., 2014). Roy et al. (2008) concluded barriers in implementing WSUD were related to: i) uncertainties in performance and cost; ii) insufficient engineering standards and guidelines; iii) fragmented responsibilities; iv) lack of institutional capacity; v) lack of a legislative mandate; vi) lack of funding and market incentives; and vii) resistance to change. Jiang et al. (2018) noted some similar barriers for Sponge Cities in China, although these were nuanced by the planning and governance systems specific to that country. BenDor et al. (2018) suggested certain research areas related to WSUD still need to be resolved, including the advantages and disadvantages of WSUD that consider biophysical constraints; maintenance and operation costs; the preferences of stakeholders and communities for different stormwater infrastructure; long-term effects on ecosystem structure and function; and improved multidisciplinary and transdisciplinary collaborations.

One of the common barriers identified to implementing WSUD is the assessment of the benefits and costs related to construction and maintenance (Polyakov et al., 2017) and as such, we will demonstrate one method - hedonic pricing of ecosystem services - that can be used to quantify WSUD benefits. While WSUD benefits are related to a reduction in flood damage, for example, they might be quantified using well-established engineering approaches, and other intangible benefits may not be accounted for, but nonetheless will be of value. Benefits may be accrued in relation to stormwater management (quantity and quality), reduced urban heat island, reduced noise impacts, air purification, biodiversity and ecosystems, human physical activity, aesthetics, social interactions, food security; health, and carbon sequestration (Mekala et al., 2015; Klimas et al., 2016; Park et al., 2017; Irvine et al., 2019; Ro et al., 2020). Collectively, these might be considered indicators of community well-being and liveability.

Ecosystem services evaluation is one approach that can be used to capture these intangible or marginal benefits and help elucidate the value of WSUD for policy-makers and community alike. Turner et al. (2011) have defined ecosystem services as *aspects of ecosystems consumed and/or utilized to produce human well-being*. The Millennium Ecosystem Assessment (MA 2005) defined four categories of ecosystem services: i) supporting (e.g. nutrient cycling, soil formation, primary production); ii) provisioning (e.g. food, water, fiber); iii) regulating (e.g. climate regulation, disease regulation, water purification); and iv) cultural (e.g. spiritual, religious, aesthetic). Subsequent to Costanza et al.'s (1997) landmark study in which it was concluded that the value of ecosystem services for the entire biosphere was USD$16-54 trillion per year (1994 dollars), with an average of USD$33 trillion per year (about double the global GNP in 1994), there has been extensive examination of methodologies to monetize ecosystem services (Loomis et al., 2000; Turner et al., 2011; Gómez-Baggethun & Ruiz-Pérez, 2011; Braat & de Groot, 2012; Christie et al., 2012; Costanza et al., 2017; Lazaridou & Michailidis, 2020). Research also has evolved beyond monetization to examine other methods (including indicator approaches and participatory mapping) in assessing ecosystem services (Christie et al., 2012; Martín-López et al., 2012; Crossman et al., 2013; Kelemen et al., 2014; Scholte et al., 2015; Wong et al., 2015; Ho et al., 2018). This paper limits itself to a monetization approach, but ultimately an approach that integrates both monetary and non-monetary indicators may be the way forward.

Ecosystem services concepts have been used to assess the values of green infrastructure (or WSUD) but in a review of 170 papers, Prudencio & Null (2018) found that less than 40% actually quantified ecosystem services. Haase et al. (2014) noted that of 217 papers they reviewed, 156 (72%) employed exclusively non-monetary indicators in urban ecosystem service assessments, while

77 (35%) used both monetary and non-monetary methods. In quantifying ecosystem services for green infrastructure, the Travel Cost Method (TCM), contingent valuation (CV) (i.e., willingness-to-pay), and hedonic pricing approaches have been used (Tapsuwan et al., 2009; Mekala et al., 2015; Lupp et al., 2016; Park et al., 2017; Polyakov et al., 2017; Kalfas et al., 2020), but there is a need to strengthen the empirical evidence of benefits provided by WSUD design and also explore possible differences in valuation characteristics. As such, the objective of our study was to empirically examine the value of WSUD features under the ecosystem services framework using a hedonic pricing approach in two communities, Geelong, Australia and Singapore. Both communities are similar in that they have aggressively pursued a policy of WSUD implementation. However, the physical, social, and policy structures of each community are very different and these differences facilitate some potentially interesting comparisons. An understanding of the hedonic pricing results was deepened through qualitative surveys in each community.

METHODS

Hedonic Price Model

We chose to use a hedonic pricing approach for this study as it has been applied extensively to assess the value of residential properties (differentiated products) in relation to the implicit prices that may be associated with bundles of amenities and disamenities (Rosen, 1974; Milon et al., 1984; Sirmans et al., 2005; Monson, 2009). The bundle of amenities and disamenities may include physical characteristics of the house, proximity to services, finances and contracting factors, and even the viewshed of the home (Sirmans et al., 2005; Cavailhès et al., 2009; Abidoye & Chan, 2017). Proximity to open spaces of various types, including parks, forests, and golf courses generally has an inverse relationship with residential selling price (Do & Grudnitski, 1995; Cho et al., 2006; Brander & Koetse, 2011). The relationship between environmental quality (e.g. air quality, clean water, proximity to industrial sites) and home sales price also has been examined using a hedonic valuation approach (Ridker & Henning, 1967; Cho et al., 2006; De Vor & De Groot, 2011). However, there has been lesser effort to date in empirically evaluating the relationship between proximity of WSUD features and selling price (see also, Polyakov et al., 2017) and we believe this an important contribution of our study.

The general concept of a hedonic pricing model can be expressed as (after Monson, 2009):

Market Price = f (tangible and building characteristics, other influencing factors) (1)

Frequently, the hedonic price equation will take the form of a least squares multiple regression (after Sander and Polasky, 2009):

$$\ln P_i = \beta_o + \beta_1 S_i + \beta_2 N_i + \beta_3 Q_i + \varepsilon_i \quad (2)$$

Where P_i is the price of the residential home, i, S_i is a vector of property parcels and structural characteristics of the residential home (e.g. lot size, number of bedrooms, age of home), i, Q_i is a vector of environmental characteristics (e.g. proximity to open space, proximity to brownfields sites, air quality, water quality), i, β_o is the constant, which represents baseline average log prices of property that are not explained by the explicit attributes, E(y), when all the predictor variables are 0; $\beta_1, \beta_2, \beta_3$, represent the change in the mean response, E(y), per unit change in the associated predictor variable when all the other predictor variables are held constant, and ε_i is an error term. For this study, the least squares multiple regression was conducted in Microsoft Excel.

Application of equation (2) assumes that the housing market is in equilibrium, such that all individuals' locational decisions are based on maximizing behaviour and equilibrium prices are determined so that buyers and sellers are perfectly matched (Rosen, 1974; De Vor & De Groot, 2011). Rosen (1974) showed that the relationships between dependent and independent variables theoretically should be non-linear, but Milon et al. (1984) noted that in practical application there was little guidance on choosing the proper functional form, and Brander and Koetse (2011) noted that linear, log-linear, log-log/ln-ln, and Box-Cox transformation forms have been reported in the literature.

Although the general form of equation 2 is the one that is typically applied, Abidoye & Chan (2017) have noted that ARIMA, fuzzy logic systems, Artificial

Neural Network (ANN), and Analytic Hierarchy Process (AHP) approaches are also increasingly being applied, particularly when big data sets are available for mining. Furthermore, advanced data analysis and visualization techniques, such as GIS, are providing new approaches to assessing the spatial aspects of amenities and disamenities (e.g. Cavailhès et al., 2009). A number of challenges and shortcomings have been identified with the hedonic pricing approach, including omitted variable bias (i.e. when an omitted variable influences property values and also is spatially correlated with the environmental quality measure of interest), elasticity of the housing market (or a market not in equilibrium), market segmentation, challenges related to changing expectations about future environmental amenity levels, inability to estimate non-use values, spatial autocorrelation, and the need for large (and sometimes sensitive) data sets (Freeman, 1981; Cho et al., 2006; Kuminoff et al., 2010; Turner et al., 2010; Abbot & Klaiber, 2011; De Vor & De Groot, 2011; Carriazo et al., 2013; Polyakov et al., 2017). Nonetheless, hedonic pricing remains a popular and intuitive approach for identifying and assessing factors influencing housing price, including environmental amenities, and as such likely will continue to be a useful tool to help value ecosystem services associated with urban areas (Sander & Polasky, 2009; Carriazo et al., 2013; Abidoye & Chan, 2017).

Field Sites

The two field sites were chosen for convenience, with Geelong, Australia being the study location for an overseas National Institute of Education, Singapore, undergraduate final year project field site and because of existing collaboration between team members. However, both communities also have a strong commitment to WSUD implementation and we felt a comparison of the two locations might provide some interesting insight to community understanding of and response to WSUD.

Geelong, Victoria, Australia

Geelong, Australia, with a population of 192,000 in 2016, is the second largest city in the State of Victoria and is situated on the western shore of Corio Bay. At only 75 km west of Melbourne, Geelong has been experiencing an increasing spillover from the commuter community in recent years and suburban development has expanded considerably. However, Geelong also has its own sense of place and was designated Australia's first UNESCO City of Design in 2017, which was a recognition of creativity and innovation in building a sustainable, resilient, and inclusive community (*Geelong, UNESCO City of Design* n.d.).

With a mean annual precipitation of 524 mm and a mean maximum and minimum temperature of 19.3 °C and 9.0 °C, respectively, (*Climate statistics for Australian locations*, n.d.) Geelong's climate is considered a marine temperate climate (Cfb) under the Koppen climate classification system. While the Geelong annual rainfall regime is relatively dry, it is occasionally hit by intense storm events of up to 100 mm in 24 hours, making it particularly vulnerable to flash floods (e.g. Liu et al., 2017b).

Greater Geelong maintains more than 200 small streetscape scale and 150 large end-of-pipe WSUD assets but our study focused on one large constructed wetland system in the Grand Lakes Estate development of Lara (Figures 1 and 2). The Grand Lakes Estate was judged the best residential estate at the 20th Urban Development Institute of Australia's Victoria Awards for its emphasis on WSUD.

Bishan Park, Singapore

Singapore is a small, city-state island located at the end of the Malaysia Peninsula. At only 716 km^2 in area (49 km east⇔west; 25 km north⇔south) and a population of nearly 6 million, planning of urban space is critical. Despite its population density at just over 8,000 people/km^2, Singapore has been identified as one of the greenest cities of the world (based on canopy cover from a study done by MIT (*Treepedia, Exploring the Green Canopy in cities around the world,* n.d.). Under the PUB's ABC (Active, Beautiful, Clean) Waters Program (*PUB ABC Waters*, n.d.) Singapore has promoted WSUD implementation extensively for the past decade to manage localized flooding and improve runoff quality entering its drinking water reservoirs (e.g. Irvine et al., 2014; Lim & Lu, 2016; Yau et al., 2017; Chang et al., 2018). Increasingly, WSUD also has been used to underpin a biophilic, urban liveability philosophy (Newman, 2014; Liao, 2019; Ho et al., 2020). Located 1.2° north of the equator, Singapore experiences a tropical rainforest (Af) climate, averaging 2,166 mm of rainfall annually, with annual maximum and minimum daily temperatures

Figure 1:
Grand Lakes Estate, Lara, with the Grand Lakes constructed wetland dominating the central part of the figure (source: Geelong Town Council).

Figure 2:
Grand Lakes constructed wetland with boardwalk (left) and sedimentation cell (right). Photos by authors.

ranging between 31-33 °C and 23-25 °C, respectively (*Meteorological Service Singapore, Climate of Singapore,* n.d.).

The frequency of high intensity rainfall poses considerable challenges to managing local flooding (Chang & Irvine, 2014), but the WSUD ABC program is efficient in helping to manage the runoff. The naturalization of the Kallang River through lower Bishan Park, completed in 2012, with a construction cost of $USD60 million ($S83.4 million), is a jewel of the ABC design program (Figure 3). The project replaced a linear section of concrete channel with a meandering, naturalized river and connected, functional, floodplain and has won a number of awards, including a World Architecture Award (2012), an Excellence on the Waterfront Honor Award (2012), and the President's Design Award Singapore (2012).

In addition to a number of small stormwater ponds and the naturalized channel in Bishan Park shown in Figure 3, the Public Utilities Board (PUB, Singapore's National Water Agency) has constructed a cleansing biotope to assist with water quantity and quality management, as well as aesthetics (Figure 4). PUB (2018) notes that cleansing biotopes "…are a form of artificially constructed vertical flow wetland, typically with recirculation. They consist of nutrient-poor substrates that are planted with wetland plants that are known for their water cleansing capacity." In the case of the Bishan Park biotope, water can be drawn directly from the Kallang River for treatment or can be recycled from the discharge pond area (Figure 4).

Data Collection

Geelong, Australia

For the hedonic pricing analysis, real estate data for all properties sold in the Grand Lakes Estate in the year 2017 (n=64) were obtained through a Real Estate Section Editor from the Geelong Advertiser, a local daily newspaper in Geelong (*Geelong Advertiser*, n.d.). The real estate data obtained for each sale in 2017 included: 1) address, 2) post code, 3) property type, 4) number of bedrooms, 5) number of bathrooms, 6) number of car parking spaces, 7) land size (m^2), 8) sales price, 9) sale and settlement date, and 10) agency. These were resale rather than new homes. The nearest linear distance of each property edge to the wetland edge was measured in Google Maps. All data were stored in an Excel spreadsheet.

In-depth key informant interviews were conducted in December, 2017, with 6 participants that were identified through contacts at Deakin University and Geelong Town Council and who live in proximity to constructed wetland WSUD features. The key informant in-depth interviews were semi-structured and were undertaken while the Singapore team was in Geelong conducting other fieldwork on WSUD features, as well as simultaneously gathering the raw data for the subsequent hedonic pricing analysis. In-depth interviews are a commonly used research method in qualitative social sciences research (Legard et al., 2003) that seek to provide rich insights into the lived experience of the stakeholders (Marshall, 1996; Dworkin, 2012). Appropriate sample size for key informant in-depth interviews is a topic of considerable discussion, but Dworkin (2012) notes anywhere from 5 to 50 may be adequate. Of the 6 key informants in this study, 5 were middle-aged and one was 65 years old; 2 were female and 4 were male; all were married and held professional jobs. Three of the participants lived in the Grand Lakes Estate and three of the participants lived in a new housing development, Armstrong/Waralilly, that also has a constructed wetland and recreational paths, similar to Grand Lakes. The key informants had lived in their current locations between 2 and 7 years.

Bishan Park, Singapore

A similar, set of real estate data were available for the Bishan Park area. The HDB (Housing and Development Board) Map Services website (*HDB Map Services*, n.d.) provides free, publicly available information on HDB flats for selected addresses. HDB is the statutory board of the Ministry of National Development responsible for public housing in Singapore. In contrast to the study area in Geelong where individual, landed homes predominant, public flats provided by HDB were home to 78.7% of Singaporean households in 2018 (e.g. Figure 3), with 15.9% of households occupying private condominiums or other apartments, and only 5.1% of households occupying landed homes (*Department of Statistics Singapore*, n.d.).

The HDB Map Services website was first accessed in January, 2018, and data for the public properties (n=155) sold around the naturalized channel area of lower Bishan Park (Figure 3) for the year 2017 were collected and entered into an Excel spreadsheet. As with the Geelong site, the Singapore data represent re-sale rather than new homes and both sites represent sales for the year 2017. The data available

Figure 3:
Bishan Park naturalized channel and floodplain (top, Google Earth Pro, imagery date 1 February 2019, Bishan Park, Singapore, 9 September 2019) and corresponding in situ photos of concrete channel draining the naturalized section of the park (lower right). The upstream park channel was concrete like this prior to 2012. Re-constructed (naturalized) river with mid-channel bars and functioning floodplain (lower left) (lower photos by the authors). HDB flats overlooking Bishan Park are observed in the background.

on the website included: 1) address, 2) postal code, 3) flat type/number of rooms, 4) apartment storey, 5) floor area (m^2), 6) remaining number of years on lease, and 7) sales price. The nearest distance of each property to Bishan Park was measured in Google Maps. It should be noted that in Singapore the designation of number of rooms for an HDB flat does not refer to bedrooms. For example, a 4 room flat would include: 3 bedrooms, 1 of which is a master bedroom with attached bathroom; living/dining area; kitchen; common bathroom; service yard; and storeroom.

Figure 4:
Cleansing biotope (above) in upper Bishan Park (a), with recirculating ponds (b) and Kallang River (c). This location is upstream of the area shown in Figure 3. Google Earth Pro, imagery date 1 February 2019, Bishan Park, Singapore, accessed 9 September 2019. Photo of the cleansing biotope (below, photo by the authors).

We were unable to get a response to our request for key informant interviews or permission to access the HDB flats in Singapore, so instead, structured, face-to-face surveys were conducted in January, 2018, with randomly selected park users. The location for the interviews was adjacent to the cleansing biotope (Figure 4) and participants were given a short briefing about biotopes to start the survey. The total number of respondents was 20, with most being middle-aged to older males and females. The sample size was small, but the qualitative results are still expected to provide insights to interpreting the hedonic price analysis, which was conducted subsequent to the face-to-face surveys.

Results

Hedonic Pricing Analysis – Geelong, Australia

Summary statistics for the variables used in the Geelong hedonic pricing analysis are presented in Table 1. As a first step in the hedonic pricing analysis, the correlation between the independent variables was assessed both in the natural log (ln) form and arithmetic (linear) form, as we sought the most appropriate and parsimonious model possible. The Pearson Product Moment correlation (r) was greatest between *Bath* and *Bed* for both arithmetic (r=0.39) and ln (r=0.41) forms. As such, we expected to eliminate one of these variables from the hedonic price analysis.

The general form of the hedonic pricing equation was:

$$\text{Sales Price/A\$} = b_o + (\text{Bath} \times b_1) + (\text{Car} \times b_2) + (\text{Size} \times b_3) + (\text{Dist} \times b_4) \quad (3)$$

where the variables are defined, as shown in Table 1. We evaluated the linear, ln-linear, and ln-ln forms of the equations. For all regressions, the variable *number of bedrooms* (Bed) was dropped from further analysis as it had the largest p-value and was highly correlated with *number of bathrooms* (Bath), as noted. The r^2 (n=64) was greatest for the ln-ln form (55.1%), followed by the linear form (46.1%), and the ln-linear form (43.2%). To help identify the appropriate form of the equation we assessed the residuals where a χ^2 test showed the residuals to be normally distributed (α=0.05) for the ln-ln form, but not the linear and ln-linear forms. The mean of the residuals for the ln-ln form was not significantly different from 0 (one sample t-test, α=0.05) and visually was homoscedastic. Although bias can be introduced in the backtransformation of the predicted logarithmic values (Ferguson, 1986; Koch & Smillie, 1986; Irvine & Drake, 1987), based on the theoretical discussions of Rosen (1974), we elected to favour the ln-ln form and the results of the regression are presented in Table 2. Table 2 shows that, as expected, distance from the wetland had a significant inverse relationship with the sales price, while the other variables were positively related to the sales price.

Table 1: Summary statistics of variables for hedonic price analysis, Geelong, Australia

Variable	Mean*	Median	Standard Deviation	Minimum	Maximum
Sales Price**	459,913	465,000	109,129	179,000	710,000
Bed	3.6	4	0.5	2	4
Bath	1.9	2	0.3	1	3
Car	1.8	2	0.7	0	4
Size	634.4	619	144.2	299	1,216
Dist	412.0	431.1	250.7	55.1	881.9

* *n=64*

** *Sales Prices – sales price of house, A$; Bed – number of bedrooms in the house; Bath – number of bathrooms in the house; Car – number of car parking spaces; Size – property lot size (m^2); Dist – nearest straight line distance from the property edge to the wetland edge (m)*

Table 2: Hedonic pricing results, Geelong, Australia, for home sales in 2017 (n=64; r^2=55.1%)

	Coefficients	t Stat	P-value
Intercept	10.41	13.1	4.3×10^{-19}
Distance from the wetland/m	-0.1077	-3.24	0.002
Bath	0.1716	1.45	0.15
Car	0.1444	4.80	1.1×10^{-5}
Land Size, m^2	0.4738	3.83	0.0003

Hedonic Pricing Analysis – Bishan Park, Singapore

Summary statistics for the variables used in the Singapore hedonic pricing analysis are presented in Table 3. As with Geelong, a first step in the hedonic pricing analysis was to assess correlation between the independent variables both in the natural log (ln) form and the arithmetic (linear) forms. The Pearson Product Moment correlation (r) was greatest between *Rooms* and *Floor Area* for both arithmetic (r=0.95) and ln (r=0.95) forms. As such, we expected to eliminate one of these variables from the hedonic price analysis.

The general form of the hedonic pricing equation was:

$$\text{Sales Price/S\$} = b_o+(\text{Storey} \times b_1)+(\text{Rooms} \times b_2)+(\text{Lease Remaining} \times b_3)+(\text{Dist} \times b_4) \quad (4)$$

where the variables are defined, as shown in Table 3. We evaluated the linear, ln-linear, and ln-ln forms of the equations. For all regressions, the variable *Floor Area* was dropped from further analysis as it had the largest p-value and was highly correlated with *Rooms*, as noted. The r^2 (n=155) was greatest for the linear form (87.4%), followed by the ln-ln form (86.0%), and the ln-linear form (83.5%). To help identify the appropriate form of the equation we assessed the residuals where a χ^2 test showed the residuals to be normally distributed (α=0.05) for all three forms. The means of the residuals for all forms were not significantly different from 0 (one sample t-test, α=0.05) but visually the linear and ln-linear residuals exhibited a curvilinear trend whereas the ln-ln form visually was homoscedastic.

Based on the theoretical discussions of Rosen (1974) and to be consistent with the comparison to Geelong, we elected to favour the ln-ln form and the results of the regression are shown in Table 4. Table 4 shows that, as expected, distance from the wetland had a significant (α=0.05) inverse relationship with the sales price. The remaining years left in the flat lease also had a significant (α=0.05) inverse relationship with the sales price, while the other variables were positively related to the sales price and were significant at α=0.05. The inverse relationship between the price and remaining years left in the flat lease is an unexpected result. New HDB flats are purchased with a 99-year lease while resale flats will have a shorter time than 99 years remaining on the lease. For most flats, the land will return to the state at the end of 99 years. As such, it is expected that flats with a longer remaining lease might command a higher resale price (i.e. a positive relationship). There may be several possible explanations for this result. First, resale flat value in Singapore appreciates, at least in the first 33 to 39 years (Chua, 2015; *PropertyGuru, The decaying HDB lease: myth or reality?*, n.d.), and therefore it is possible the Bishan flats that are slightly newer have not appreciated to the same level. It also is possible that there were specific local characteristics (i.e. the omitted variable issue) such as different flat (e.g. renovations) or building/block amenities that influenced results. Finally, the range of the remaining lease years is small (Table 3), as the housing developments in this area would have been constructed around the same time and this small range may be influencing the results. We re-calculated the regression without including the Lease Remaining variable and this reduced the marginal implicit price of the distance to the WSUD feature (see discussion below) by 10% and reduced the r^2 to 83.1%. As such, we retained the Lease Remaining variable in the analysis, but recognize this is an issue that would be interesting to explore further.

Table 3: Summary statistics of variables for hedonic price analysis, Singapore

Variable	Mean*	Median	Standard Deviation	Minimum	Maximum
Sales Price**	685,819	635,000	140,992	405,000	955,000
Storeys	7.7	8	4.0	2	17
Rooms	4.6	4	0.8	4	6
Floor Area	119.8	113	17.2	101	150
Lease Remaining	73.9	74	0.7	73	75
Dist	189.0	157.5	102.7	40.0	436.6

* *n=155*
** *Sales Price – sales price of flats in each specific HDB block, S$; Storey – apartment storey of the sales in each specific HDB block; Rooms – number of rooms in each flat sold; Floor Area – floor area of the flats sold in each specific HBD block (m^2); Lease Remaining – number of years remaining in the lease of the flats sold in each specific HBD block; Dist – nearest straight line distance from the HDB building edge to the edge of Bishan Park (m)*

Table 4: Hedonic pricing results, Singapore (n=155; r^2=86.0%)

	Coefficients	t Stat	P-value
Intercept	22.75	7.96	3.9×10^{-13}
Distance from the wetland/m	-0.025	-2.28	0.024
Storeys	0.066	6.07	9.8×10^{-9}
Number of Rooms	1.08	26.6	1.2×10^{-58}
Lease Remaining/years	-2.55	-3.85	0.0002

Key Informant Interviews – Geelong, Australia

The majority of interviewees had a certain degree of understanding about wetlands as a form of stormwater management strategy, with some exhibiting very detailed knowledge because of their professional training. One interviewee said that Lara (the Grand Lakes area she lives in) used to be prone to flooding but new estates with wetlands are better protected. Of the 6 interviewees, only one did not know that wetlands are a form of stormwater management strategy but this interviewee was still able to briefly describe that wetlands are good for the environment. Therefore, in general, awareness of the wetland functions was high with the key stakeholder group.

All six of the interviewees who reside near a wetland mentioned that they enjoy having a wetland in their estate; all noted that they appreciated the openness of the wetland, which facilitates participation in different activities. For instance, one interviewee explained that the wetlands can be utilised for family bonding activities such as barbeque sessions. Another interviewee who has three children, mentioned that the wetland is a very nice open space, where her children can go to play, ride bikes, and watch the birds. Interviewees with children typically mentioned that the presence of wildlife was enriching for their children. Besides the physical desirability of the wetlands, two of the six interviewees also mentioned the "financial desirability" of the wetlands where both of them saw investment potential in buying a property next to the wetland; as one noted: "*It is good for the environment, and it certainly improves the value. If your property is facing the wetland, you have 20% premium for the property.*"

While all interviewees enjoyed their experience staying near a wetland, some concerns were expressed about the increased presence of mosquitoes and snakes in the summer. In general, the interviewees believed that proper and good management of the wetlands is crucial in ensuring the desirability of the wetlands. The consideration of how and who should bear the cost for maintenance is critical and should be explored in more detail. Furthermore, one interviewee pointed out that due to the open access of the wetlands, people from other parts of Geelong also utilised them, which led to an increase in human traffic near his house.

The interviewees were asked whether proximity to the wetlands was one of the factors that they considered when they bought their current property. All six of the interviewees mentioned that proximity was only a bonus factor and the key factors that they looked at mainly were the price, size of backyard, proximity to workplace and amenities, ability to customise their design, and personal considerations. Despite the fact that all respondents indicated the presence of a wetland was not part of their current location decision, four out of the six interviewees mentioned that they may be willing to pay slightly more for increased proximity to the wetlands, and as noted above, two of the interviewees identified the now-perceived financial desirability of living near the wetland.

Qualitative Surveys – Bishan Park

When asked, 55% of respondents already were aware of the cleansing biotope/wetland in the park. Interestingly, 42% of respondents indicated that living near the park was one factor that influenced their decision to purchase a flat nearby and 70% said they would be willing to pay more to live near a park. One participant, in discussing why they chose to live near the park indicated, "*I can meet with friends to do taichi in the park; the park is also a factor for price increment.*" However, respondents noted that other factors also influenced their flat purchase decision, including proximity to amenities (79%), price (63%), flat size (26%), floor level (26%), number of rooms (26%), and number of years remaining on lease (5%). Said one respondent, "*I am very practical and I think that amenities like shopping centres and MRT are more important.*"

DISCUSSION

For both Geelong and Singapore, a significant (α=0.05) negative, non-linear relationship was found between home sale price and the distance to the WSUD feature, which suggests that there is an initial rapid decline in value moving away from the WSUD edge, with the value continuing to decrease, but at a slower rate, as distance increases, until some minimum sales impact is reached. The marginal implicit price of the distance to the WSUD feature was calculated using the mean distances reported in Table 1 (Geelong, 412 m) and Table 3 (Singapore, 189 m) and where the other variables retained in the hedonic price analysis (Tables 2 and 4) also take on the mean values (from Tables 1 and 3). Following the approach used by Tapsuwan et al. (2009), at the mean distances from the wetland, a property in Geelong will experience a reduction in sales price of approximately A$117 (S$106) if the property were to be 1 m further away from the wetland and in Singapore the reduction would be S$92 (A$101). A number of studies have suggested that the price effect of green space (including parks, wetlands, forests, and golf courses) will be less with distance and at some point, in essence, there would be no measurable impact, but that threshold distance has variously been reported in the range of 100-1,700 m (Do & Grudnitski, 1995; Cho et al., 2006; Cavailhès et al., 2009; Sander & Polasky, 2009; Tapsuwan et al., 2009; Brander & Koetse, 2011; Polyakov et al., 2017). The size, shape, and number of WSUD features also potentially could impact selling price of the home (e.g. Cho et al., 2006; Sander & Polasky, 2009; Tapsuwan et al., 2009; Engstrom & Gren, 2017). We did not explore the impact of these variables in our analysis as the large size of the constructed wetland and Bishan Park would be the dominant natural focal point for each of the study areas and we therefore attributed the ecosystem service benefits entirely to these features. However, an important element of WSUD design is that it is decentralized and distributed spatially. This scale aspect and its implications for hedonic pricing results should be explored further. For example, ecosystem services associated with biodiversity, qualitatively should be greater for larger patch areas, while smaller, decentralized WSUD features might be valued by condominium owners or in gated communities as a landscaping feature. Similarly, additional features such as neighbourhood characteristics (N_i in equation 2) might be considered in a future study as might a modified hedonic analytical (difference-in-differences) approach to more fully assess omitted variable bias concern (e.g. Pope & Pope, 2015; Saengchote, 2020). Given these cautions, it can be concluded the hedonic pricing results suggest that in both study locations WSUD features provide positive ecosystem service values that can be reflected by market analysis. For comparison purposes, hedonic pricing results for wetlands, parks, and a restored lake from sites around the world are shown Table 5. The values shown in Table 5 represent considerable range and must be interpreted with some caution given the differences in locations and market values represented, differences in types of green/blue landscape evaluated, and differences in calculation methodology. Our results fall within, but towards the higher end, of the range presented in Table 5. Despite the variability, Table 5 does emphasize two points. First, it generally can be seen that hedonic pricing consistently shows an inverse relationship between distance from a WSUD feature and selling price of a home; and second, it is essential to conduct local (site specific) studies when quantifying the ecosystem services through hedonic pricing for that site.

The interviews and qualitative surveys support the hedonic pricing results. In both locations, study participants generally enjoyed living near a wetland/ greenspace, although Singaporeans included other more important concerns in their purchase decision making, including proximity to amenities, price, flat size, floor level, and number of rooms. The hedonic pricing analysis for Singapore captured 86.0% of the data variability, which was greater than the Geelong site, and may reflect the emphasis that urban-focused Singaporeans have in making a purchase decision, particularly in relation to property parcel and structural characteristics of the residential home (S_i in equation 2). Residents in both Geelong and Singapore were observed to use the WSUD features for a number of healthy activities and this serves to support community well-being or a “liveable community”. Those interviewed generally valued the WSUD features and in fact, many would be willing to pay a premium to live adjacent to such features.

Both Singapore and Geelong have successfully mainstreamed WSUD within their communities. As such, the question may be raised as to whether

Table 5: Hedonic pricing estimates for wetland and greenspace value, A$

Source	Value, A$	Comment	Location
Tapsuwan, 2009	$42.40	Marginal implicit price of the distance to the wetland based on a 1 m increase from the mean distance and holding the mean value of other variables constant (ln-linear form)	Perth, Australia, greenspace
Weber et al., 2015	$24	Marginal implicit price of the distance to the remediated lake based on a 1 m increase from the mean distance and mean selling price of home (ln-linear form)	Lake Illawarra, NSW, Australia
Park et al., 2017	$475	Expressed as a one unit increase in distance from a park. Additionally, it was noted that an increase in distance from the park going from 200 m to 300 m would decrease the value of the home by A$17,472 (ln-ln form)	Seoul, South Korea, large park
Kolbe and Wustemann, 2014	$10.35	Marginal implicit price expressed as a one-unit (meter) increase in distance from parks (ln-linear form)	Cologne, Germany, urban parks
Cho et al., 2006	$264-$566/1000 ft (305 m)	Marginal implicit price based on mean price and an initial distance of 1 mile, moving 1,000 ft (305 m) closer to a park or greenway (locally-weighted, ln-ln form)	Knox County, Tennessee, parks and greenways
Syafiqah et al., 2017	$1,580	Expressed as a one-unit increase in distance from the wetland where one-unit is 100 m (ln-linear form)	Putrajaya, Malaysia, wetland parks

there are common factors that might have resulted in this success. Certainly, the two communities have different physical (climate, population density), socio-political, and planning characteristics that might potentially lead to different end markers with respect to WSUD implementation. The literature is replete in comparing differences between Singapore and Australia on a diversity of topics, ranging from transportation planning to purchase making behaviour, to entrepreneurialism (e.g. Leo et al., 2005; Hale & Charles, 2008; Tham, 2016). Urban planning and policy-making in Singapore traditionally was influenced by its British colonial heritage, as reflected in its British Town and Country Planning Act of 1947, although modern reform and hybridization subsequently occurred (Yuen, 2011). Singapore has a single government that is generally well integrated with respect to urban planning, including water resource planning and management (Yuen, 2011; Luan, 2010; Irvine et al., 2014). Water is a matter of national security and in addition, due to its high population density, Singapore has employed an advanced, closed loop approach to water management that is overseen by one agency, the PUB. In Australia, while the state government will determine policy direction, planning and implementation of programs generally is handled by local government, particularly in relation to the environment (Morison & Brown, 2011).

Some have suggested that Asian cultures are more collectivist while western cultures are more individualistic (e.g. Leo et al., 2005); although, to the contrary, Heinke & Louis (2009) found Asian and European-Australian students to be equally collectivist. The way in which we should position ourselves in relation to nature has been addressed in relevant catechism of both Western and Eastern religions, including Buddhism, Hinduism, and Islam (e.g. Dwivedi, 1993; James, 2003; Abedi-Sarvestani & Shahvali, 2008). White's (1967) seminal and much-debated work suggested that Christian philosophy emphasizing humankind's dominion over nature was an important contributing factor to the environmental crisis. Similarly-themed ideas were expressed by renown landscape architect Ian McHarg (McHarg & Mumford, 1969) in the landmark book *Design with Nature*. Such discussions led others to more deeply explore Eastern philosophy and religion emphasis on living in harmony with nature as a possible alternative to address ecological problems (Rolston, 1987; Callicot & Ames, 1989). These reflections suggest there may be nuanced differences in the approaches to green space and WSUD planning between Australia and Singapore. Both western and eastern cultures have a history of valuing green space (Howett, 1998; Fukamachi et al., 2000; Jones, 2018) although Miao (2001) also notes that urban public places in Asian and Western cities may represent different form and function.

In their very forward-thinking work, Wong & Brown (2009) suggest that a water sensitive city should have a seamless integration of three key pillars of practice (or the triple bottom line) of: i) *Cities as Water Supply Catchments* in which a diversity of water sources underpins both centralised and decentralised infrastructure; ii) *Cities Providing Ecosystem Services*; and iii) *Cities Comprising Water Sensitive Communities* that must provide and embrace socio-political capital for sustainability and water sensitive decision-making and behaviours. Singapore has developed a diversity of water supply through its Four National Tap program (Irvine et al., 2014), per Wong and Brown's pillar (i). Interestingly, however, while Singapore, with its significant minority Muslim population, was able to successfully establish a reused water program, some Australian communities have been unable to obtain community buy-in for this option (Fielding et al., 2019). Possibly, this represents a more collectivist society approach in Singapore. This paper demonstrates that both Geelong and Singapore provide ecosystem services through WSUD. Friess (2017) notes that although not monetized, Singapore has a long history of policy support for ecosystem service considerations. Perhaps the most critical comparison for our paper is Wong & Brown's (2009) pillar (iii), regarding socio-political capital, and this is where some areas of Australia and Singapore may differ. Morison & Brown (2011) have reported that local implementation of WSUD in Australia has been uneven. One of the factors they identified as producing uneven implementation is what they termed "policy without publics" in which there was little community support despite the policy. It was suggested policy without publics occurred in some Melbourne municipalities because a narrow definition of WSUD focusing on stormwater management did not capture the general public's interest. Furthermore, some municipalities having limited WSUD commitment did not have the environmental or economic assets found in the municipalities of high commitment. Intriguingly, Iftekhar et al. (2019) found that survey participants living in private housing in Singapore had a higher willingness-to-pay for ABC Waters features compared to the respondents in public housing. Policy fragmentation, poor coordination, and council silos also were considered barriers to implementation of WSUD in Australia (e.g. Roy et al., 2008; Morison & Brown, 2011). Finally, Gardiner & Hardy (2005) concluded that WSUD often is thought of as an individual design solution rather than being integrated holistically into the community design and therefore fails to gain traction. With its single government, single agency approach to urban planning and water resource management, Singapore seems to have overcome policy fragmentation and has effectively implemented holistic planning. Yet, Geelong also has overcome these challenges, in part due to an engaged town council (e.g. UNESCO City of Design designation), but also, as suggested by the surveys in this study, due to a supportive and knowledgeable public. The local champion, combined with a knowledgeable public, apparently overcomes the issue of policy without publics. Singapore's top-down approach to policy suggests there may be a less engaged community, but the surveys in this study indicate that while Singaporeans may be pragmatic, many also enjoy ecosystem amenities and a biophilic lifestyle. The common denominator for the successful implementation of WSUD in Geelong and Singapore seems to be an engaged society that is concerned about sustainability, environment, and liveability. We suggest that the hedonic pricing approach to valuing ecosystem services may help to support WSUD visioning.

CONCLUSION

Hedonic pricing has now become a standard approach to evaluate environmental amenities and ecosystem services despite a number of challenges and shortcomings that have been identified, including omitted variable bias, elasticity of the housing market, market segmentation, challenges related to changing expectations about future environmental amenity levels, system non-linearity, challenges to estimate non-use values, and the need for large (and sometimes sensitive) data sets. A hedonic pricing approach, together with in-depth interviews and surveys, showed that WSUD features in Geelong, Australia, and Singapore, provide economic, environmental, and well-being benefits to the communities. Such information provides empirical evidence that can be used to encourage implementation of stronger WSUD considerations in local planning codes and also show private developers that there is a value to innovative green design. Although the sample sizes and timeframe of data analysis (home sales for the year 2017 only) was admittedly small, in both communities the selling price of the home increased significantly (α=0.05) with proximity to the WSUD feature, and this result also has been reported by others throughout the world. Holding other variables constant, the marginal implicit price for the constructed wetland in Geelong was $A117 ($S106) if the property was 1 m further away than the mean distance to the wetland, while for Singapore moving 1 m further away from mean distance to Bishan Park and cleansing biotope had a marginal implicit price of $S92 ($A101). We do note that neighbourhood characteristics for which we did not collect data might increase the explanatory power of the hedonic pricing models and such data collection should be considered as part of model refinement in the future, as should the difference-in-differences analytical approach.

While the hedonic pricing analysis in some way reflects the value of WSUD features, it should only be one of several lines of support for WSUD visioning and implementation, with other support coming from liveability or community wellbeing indices, and community and developer consultations, for example. There is not a one-size-fits all approach to effective WSUD visioning and we conclude that both Geelong and Singapore have successfully implemented WSUD programs, despite climate, planning, policy, and social differences. However, common elements of successful WSUD visioning appear to be an engaged society and key government officials concerned about sustainability, environment, and liveability.

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