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ARTICLE

How are neighbourhood design features valued across different neighbourhood types?

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Abstract In this paper, we examine whether implicit prices of neighbourhood design features in the housing market vary significantly across traditional, neo-traditional, and conventional suburban neighbourhood types. The set of neighbourhood design features we examine here include neighbourhood development density, street network connectivity, pedestrian access to transit and commercial stores, and land use mixture. Using data from Washington County, Oregon, we first use statistical procedures to identify distinct neighbourhood types. We then employ hedonic price analyses and a series of spatial Chow tests to obtain implicit prices of design attributes for houses in each neighbourhood type. We find that traditional design features such as higher street network connectivity and better pedestrian access to transit and commercial stores are valued more in the traditional and neo-traditional neighbourhoods, and that conventional neighbourhood features such as lower housing density and higher degree of homogeneous land uses are valued more in the suburban neighbourhoods.

Keywords Neighbourhood design · Housing submarket · Hedonic price

1 Introduction

During the past decade, American communities have seen emerging interests that have focused on reshaping the urban landscape to offer remedies to problems associated with sprawling developments such as disintegrating communities, faltering urban centres, exacerbating pollution and traffic congestion, and degrading natural environments. The "smart growth", "neo-traditional development" (or "new urbanism"), and other land use reforms are ever-growing trends seen throughout the country altering the style of sprawling

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residential developments in the U.S. There has been a rapid growth in neo-traditional housing developments during the past decade. In 2000, there were approximately 410,000 housing units (built or planned) in 380 new urbanism developments crossing 38 states (Congress of New Urbanism [CNU] 2004). These new styles of housing developments, characterized by increased housing density, interconnected street networks, enhanced transit accessibility, greater allocation of public space and mixed-use building types, began to flourish and play a significant role in shaping the urban landscape (Song 2005). As a result, new homes today, instead of being built in homogeneous conventional suburbs, are built in many different types of neighbourhoods with varied design features in lot size, density, street network design, land use mix, open space, and transit accessibility (Song and Knaap 2007).

On the other hand, suburban residential developments, characterized by low density, private yards, winding cul-de-sac streets, urban fringe locations without access to transit, and homogeneous tracts of single-family houses, continue to dominate and prosper (Song and Knaap 2007). In communities across the U.S., consumer choice between the above described two housing types is one of the hottest political and social issues being dealt with today.

Despite the juxtaposition of these residential developments with diverse neighbourhood design styles, little is known about whether these different types of residential developments constitute distinct housing submarkets. Previous studies relied on survey techniques or visual presence methods (Malizia and Exline 2003) and confirmed the existence of differentiated preferences for neighbourhood design features: some consumers prefer suburban conventional neighbourhood features and others prefer compact, pedestrian-oriented neighbourhood characteristics. To our knowledge, however, no prior empirical analysis has been carried out to examine whether varied neighbourhood design features are valued differently across neighbourhood types (e.g., traditional, neo-traditional, versus suburban developments). In other words, no prior study has examined, first, the extent to which implicit prices paid for specific housing and neighbourhood attributes vary across different neighbourhood types, and second, whether such variation reflects differences in demand and/or supply considerations. The purpose of this study is to contribute to this theme by examining the *first* of these two issues.

Clearly, housing contains a bundle of characteristics ranging from housing characteristics to surrounding built environment features. In the same way that an element of demand might seek out a property of a certain age, design, or the brand image of a certain builder (Leishman 2001), other factors being equal, an element of demand for property might also seek out neighbourhood design styles. Here, we conduct a formal analysis to determine whether the relationship between neighbourhood design features and house price differs across different neighbourhood types. For example, does neighbourhood connectivity have the same impact on house price in neo-traditional developments as it does in suburban developments? With that objective in mind, using data from Washington County, Oregon, we first use statistical procedures to stratify the urban built environment by distinct neighbourhood types. We then employ hedonic price analyses and a series of spatial Chow tests to obtain implicit prices of design attributes for houses in each neighbourhood type.

The remainder of the paper is divided into four sections. In the section below, we review prior studies on housing market segmentation. Next, we describe the study area, data, and methods used in this study. Then, study findings are presented. In the last section, we summarize our findings and derive implications for future research and policy.

2 Previous studies on housing market segmentation

To determine whether the relationship between neighbourhood design features and house price differs across neighbourhood types is a task akin to identifying housing submarkets. Numerous studies have agreed upon the existence of housing submarkets in a large market (for example, Goodman and Thibodeau 1998; and Bourassa et al. 1999, 2003). A submarket can be defined as a set of properties that are close substitutes for one another, but relatively poor substitutes for the properties in other submarkets (Grigsby et al. 1987; Rothenberg et al. 1991). That is to say, properties within a same submarket should be more "similar" than properties in another submarket, where similarity is measured by both physical stock characteristics and the rents that properties command (Maclennan and Tu 1996).

The appropriate method for defining submarkets depends on the purpose of the analysis (Bourassa et al. 2003). A simple attempt to define residential submarkets is to adopt a priori criteria. For example, an earlier approach of classifying submarkets is offered by Palm (1978), who argues that information flow controlled by real estate agents and search costs can segment an urban housing market into different submarkets and therefore asks real estate agents to provide information inputs in defining submarkets. Bourassa et al. (2003) confirm the accountability of submarkets defined by real estate appraisers. Another approach of delineating housing markets is based on socio-economic characteristics (Schnare 1980; Harsman and Quigley 1995). For example, Schnare (1980) discovers that, in several major U.S. metropolitan areas, different prices per unit of housing services are evident across housing submarkets defined by socio-economic differences of the dwellers. Housing submarkets can also be defined by local jurisdictional boundaries (Adair et al. 1996), physical characteristics of dwellings (Bajic 1985), or dwelling types (such as detached versus attached) (Adair et al. 1996). In addition, residential submarkets can be defined by statistical procedures which allow data to determine which characteristics are most distinct among dwellings and then cluster the properties based on those characteristics (Bourassa et al. 1999). Using statistical procedures to test for the existence of submarkets, hedonic housing price models are estimated for each submarket and for the pooled market, and Chow tests are employed to test for attribute parameter equality across submarkets (Leishman 2001). To compare different classifications of submarkets, standard errors of hedonic equations can be used to determine the best classification of submarkets (Bourassa et al. 1999).

All together, considerable research confirms that residential submarkets can be defined using either a priori or statistical procedures. Specifically, submarkets can be defined on the basis of dwelling type, dwelling characteristics, demographic and/or socio-economic composition of neighbourhoods, geographic areas, local political boundaries, or market areas perceived by real estate agents. To date, however, there have been no studies incorporating built-environment design features in the classification of housing market. We attempt to do so in this study.

3 Study area, data, methodology and variables

3.1 Study area and data

Our study area is Washington County, the western portion of the Portland metropolitan area (see Fig. 1). The study area, Washington County, contains the cities of Beaverton,

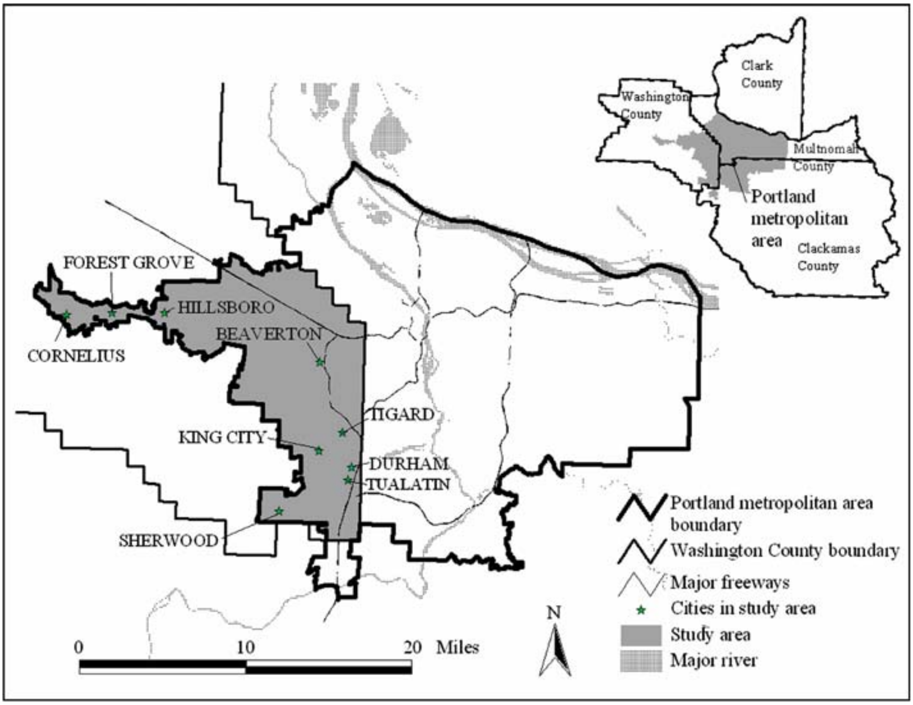

Fig. 1 Portland metropolitan area and study area

Hillsboro, Tigard, Sherwood, Tualatin, King City, Cornelius, Forest Grove, and Durham. It is in the western side that most recent growth and sales have taken place (the eastern side has an older housing stock), allowing us to capture a broader range of neighbourhood types.

The study area is further divided into traditional, neo-traditional, and conventional suburban neighbourhood types: by using cluster analyses, neighbourhoods are grouped into these different types based on the similarity within a set of predetermined design features of neighbourhoods. Details on methods of classification are provided in the Appendix.[1] Specifically, the traditional neighbourhood type includes urban core neighbourhoods, the neo-traditional neighbourhood type includes neo-traditional greenfields, and the suburban neighbourhood type includes middle ring suburban and outer ring suburban neighbourhoods (Fig. 2).

Figure 2 presents locations of different neighbourhood types. The one traditional neighbourhood type—*Urban Core Neighbourhood Type*—is composed of neighbourhoods in downtown and inner ring suburbs of the cities of Beaverton, Hillsboro, Tigard, Sherwood, Tualatin, Cornelius, and Forest Grove. The *Neo-traditional Greenfields Neighbourhood Type* contains newly-developed neighbourhoods located at urban fringe. The two suburban neighbourhood types—*Middle Ring and Outer Ring Neighbourhoods*—

[1] We then asked real estate agents the question whether the boundaries between traditional and neo-traditional, and suburban neighbourhoods are consistent with their perceptions of market areas. The consistency between the statistically determined boundaries and the perceived market areas by real estate agents confirms the reliability of the classification of neighbourhood types.

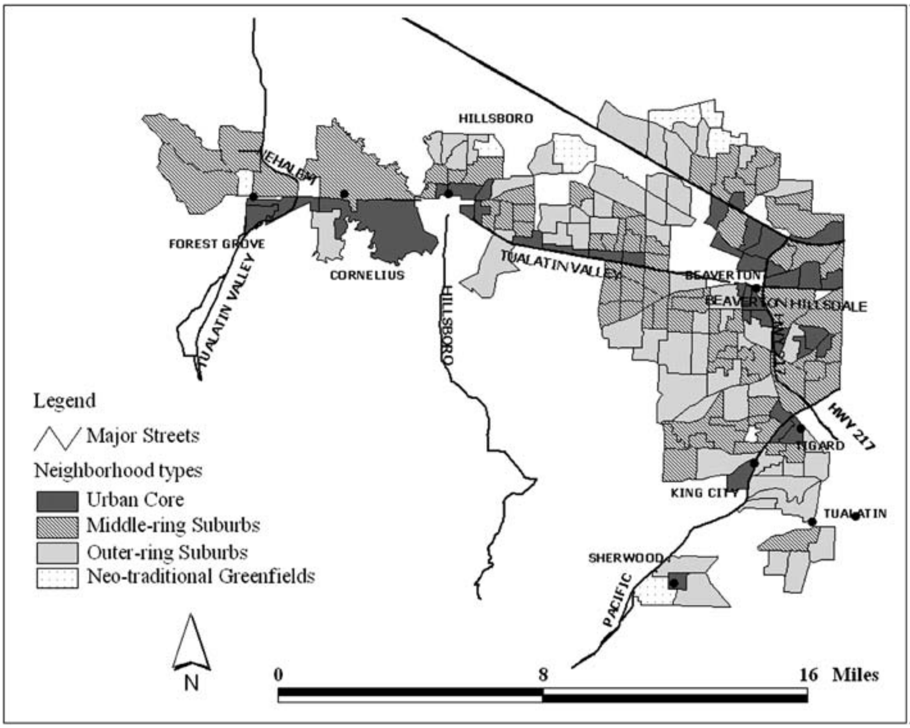

Fig. 2 Location of neighbourhood types

represent post-war suburban neighbourhoods that surround the urban core neighbourhoods and that are further away from the urban core respectively.

Not surprisingly, neighbourhood design features vary by neighbourhood type (see Fig. 3). The *Urban Core* neighbourhoods are characterized by design patterns such as grid (or modified rectilinear grid) street networks, small lots, high density housing development, accessible bus services, abundant mixed land uses such as commercial and multi-family residential uses, but deficient open spaces. The newly-developed *Neo-traditional Greenfields* neighbourhoods resemble neo-traditional developments in their modified grid and connective street networks, high density, moderate accessibility to bus stops, and ample multi-family residential uses. However, it is necessary to note that these neighbourhoods are only partially "neo-traditional" due to the general absence of commercial uses and the neighbourhoods' disengagement from the rest of the region. Of the two types of suburban neighbourhoods, the *Middle Ring* neighbourhoods represent much of the post-war suburban features such as relatively large lots of a uniform size and shape, curvilinear and exceedingly wide streets, winding cul-de-sacs, predominant detached single-family homes, and a lack of non-residential land uses and transit services; and the *Outer Ring* neighbourhoods resemble middle ring neighbourhoods in many dimensions with some cul-de-sacs, curvilinear streets, large homes and lots, and an absence of mixed land uses and transit services. Outer Ring neighbourhoods are distinct in their inviting natural environment with lavish open spaces. These findings on differentiated neighbourhood design features are consistent with the study by Song and Knaap (2007).

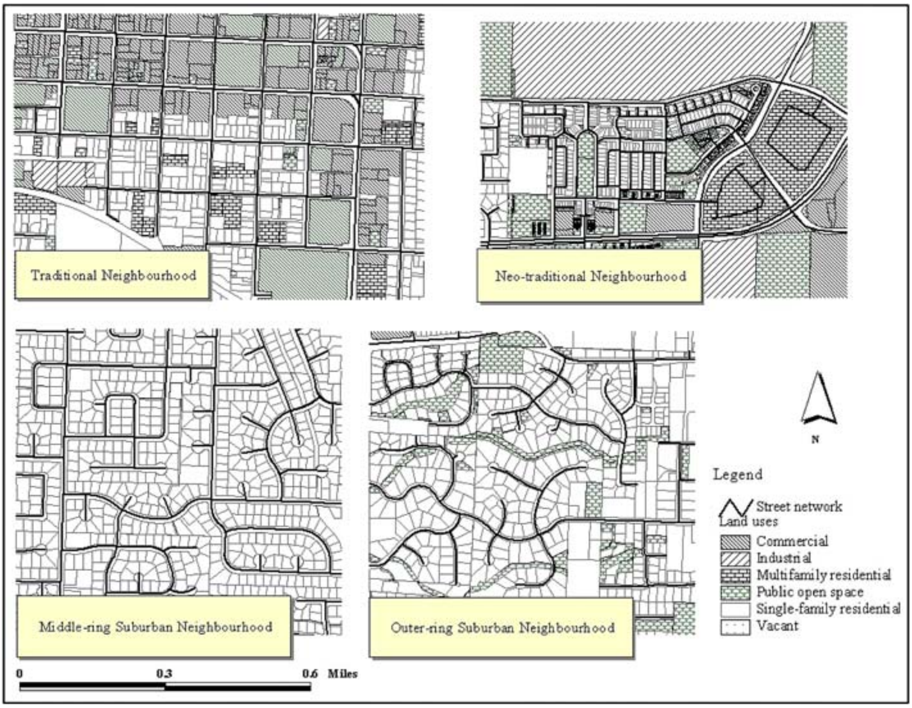

Fig. 3 Neighbourhood design features across neighbourhood types

To examine whether implicit prices of neighbourhood design features vary significantly across traditional, neo-traditional, and suburban neighbourhood types, we estimate hedonic housing price functions for the entire market and for each neighbourhood type. To do so, we collect sales data on single-family residential properties sold in the year 2000. Prior to estimation, invalid transactions and multiple sales are omitted to ensure that sales reflect market-clearing prices.[2] The cleaned dataset contains 4,314 real estate sale transactions in our study area. The average sale price in this period is $187,095, with prices ranging from $68,000 to $800,000. We assign single-family sale transactions to different neighbourhood types based on sales locations.

3.2 Methodology and variables

We take the following procedures to examine whether housing submarkets can be defined on neighbourhood design considerations. First, hedonic housing price functions are estimated for the entire market and for each potential market segment defined by neighbourhood type. Second, a series of Spatial Chow tests are conducted to identify whether there is a significant difference between a pair of regression equations under the null

[2] We removed non-arms-length transactions and prevent coding errors based on the ratio of sale price to assessed value. Transactions that have a sale price that is 60 percent greater than the assessed value or that is less than 60 percent of the assessed value are deleted from the data set. In addition, properties with lots greater than two acres, or age older than 80 years are excluded to maintain a homogeneous pool of transactions. Furthermore, we removed the transactions if their assessed value of the land is less than $1.00 per square foot or the assessed value of the improvements is less than $25.00 per square foot.

hypothesis that the two models are equivalent. If it is possible to reject the null hypothesis, market segmentation will have been identified.[3] We discuss more details of the above mentioned two methods below.

Researchers use hedonic modeling to estimate the marginal implicit prices of characteristics of a differentiated market good such as housing. The hedonic price function is implemented by treating price as a function of the quantities of a good's characteristics. The marginal implicit price of any of the good's characteristics is obtained by differentiating the hedonic price function with respect to the attribute. We employ a semi-log model[4] and specify the following: $\ln(Sale\_Price) = \alpha + \beta_i X_i + \varepsilon_i$ where α is the constant, β_i are coefficients, and X_i are independent variables including: (1) physical housing attributes; (2) public service levels; (3) location; (4) amenities and disamenities; (5) socio-economic characteristics; and (6) neighbourhood design features. To capture differences in physical attributes we include three variables: lot size (LOTSIZE), floor space (FLOORSPACE), and building age (AGE). The value of public services is also widely known to affect housing values. To capture these effects we include three variables: if the location of the sale is within an incorporated municipality (INCITY), the mean Scholastic Aptitude Test score (SAT) of a school district, and the adjusted property tax rate (TAXRT). According to economic theory, access to employment centres is a fundamental determinant of location rents. We thus include measures of distance to three central business districts: Portland (PORTCBD), Hillsboro (HILLCBD), and Beaverton (BEAVCBD). Environmental amenities and disamenities have direct effects on resident utilities and thus can also affect property values. To capture the effects of general amenities we include four measures, including proximity to a golf course (GOLF), minor roads (MINRDDIS), and major roads (ONMAJRD) and views of the Cascade and Coast Range mountains (MOUNTNVW). Residents care about social structure of their neighbourhood. We therefore include measures of racial composition, measured as per cent of the white population (PCTWHITE), and neighbourhood median household income (MEDINC). Finally, of most interest to this study is to examine how the neighbourhood design features are valued in different housing segments. Several measures of neighbourhood design features are developed to quantify internal (INTCON) and external connectivity (EXTCON) of street circulation systems, dwelling unit density (SFRDNSTY) and population density (POPDNSTY), level of mixture of all land uses (LUMIX) and non-residential land uses (NRMIX), and pedestrian walkability to commercial uses (PEDCOM) and bus services (PEDBUS).

We provide more information on the definitions and measurements of the above variables in Table 1. Summary statistics for the dependent variable and all independent variables are provided in Table 2.[5]

4 Empirical results

Results from the hedonic price analyses for the whole study area as a single market and for each of the neighbourhood types are shown in Table 3.

[3] The cause of the segmentation, however, will not be identified and is beyond scope of this research.

[4] Results from Box-Cox transformation indicate that a semi-log functional form is appropriate. This is also consistent with Song and Knaap's (2003) hedonic price study using the same dataset.

[5] To simplify the presentation, we do not include summary statistics by each neighbourhood type here. The information is available from the authors.

Table 1 Definition of independent variables used in hedonic price analysis

Variable	Definition and measurement
Property physical housing attributes	
LOTSIZE	Lot area in square feet.
FLOORSPACE	Building area in square feet.
AGE	Age of the building in years.
AGESQUARE	Square of the age variable.
Public service levels	
INCITY	Dummy variable indicating if the house is located within city limit.
Scholastic Aptitude Test (SAT)	(Scholastic Aptitude Test) SAT score in the school district in which the house is located.
TAXRT	Property tax rate for the tax district in which the house is located.
Location	
PORTCBD	Distance in feet from the property to Portland CBD.
HILLCBD	Distance in feet from the property to Hillsboro CBD.
BEAVCBD	Distance in feet from the property to Beaverton CBD.
Amenity and disamenities	
GOLF	Actual area of golf course in the neighbourhood divided by number of housing units in a neighbourhood.
MOUNTNVW	Dummy variable indicating whether the property has a mountain view (1 = Yes, 0 = No).
MINRDDIS	Distance in feet to the nearest minor road, where minor road includes major collector and collector.
ONMAJRD	Dummy variable indicating whether the property is within 150 feet of a major road (1 = Yes, 0 = No).
Socio-economic characteristics	
PCTWHITE	Percentage of population that is white in the neighbourhood.
MEDINC	Median household income in the neighbourhood.
Neighbourhood design	
INTCON	Number of street intersections divided by the number of intersections plus the number of cul-de-sacs; the higher the ratio, the greater the internal connectivity.
EXTCON	Median distance between Ingress/Egress (access) points in feet; the greater the distance, the poorer the external connectivity.
SFRDNSTY	Single-family residential (SFR) dwelling units divided by the residential area of the neighbourhood; the higher the ratio, the higher the density.
POPDNSTY	Number of households divided by area of the neighbourhood; the higher the ratio, the higher the population density.
PEDCOM	Percentage of SFR units within one quarter mile of commercial uses; the greater the percentage, the greater the pedestrian accessibility.
PEDBUS	Percentage of SFR units within one quarter mile of bus stops; the greater the percentage, the greater the pedestrian accessibility.
LUMIX	A diversity index $H_1 = \frac{-\sum_{i=1}^{6}(p_i)\ln(p_i)}{\ln(s)}$ where H_1 = diversity of all land uses including Single Family Residential (SFR), p_i = proportions of each land use type such as SFR, MFR, Commercial, Industrial, Public institutional and Park uses, and s = the number of land uses. In this case $s = 6$. A higher value indicates more evenly distributed land uses.

Table 1 continued

Variable	Definition and measurement
NRMIX	A diversity index $H_2 = \frac{-\sum_{i=1}^{s}(p_i)\ln(p_i)}{\ln(s)}$ where H_2 = diversity of non-residential uses, p_i = proportions of each land use type such as MFR, Commercial, Industrial, Public institutional and Park uses, and s = the number of land uses. In this case $s = 5$.

Table 2 Summary statistics of all variables

Variable	Unit of measures	Mean	Std Dev	Minimum	Maximum
Dependent variables					
SALE_PRICE	Dollar	187095	52782	68000	800000
LOGSALEPRICE	Log (dollar)	12.09	0.31	11.13	13.59
Independent variables					
(1) Property physical structural characteristics					
LOTSIZE	Square feet	8649.59	5261.62	250.58	82710.22
FLOORSPACE	Square feet	1783.78	662.69	456.00	7130.00
AGE	Year	22.31	17.18	1.00	81.00
AGESQUARE	Year	792.63	1081.18	1.00	6561.00
(2) Public sector characteristics					
INCITY	Binary	0.56	0.50	0.00	1.00
SAT	Score	537.77	13.67	501.00	548.27
TAXRT	Milrate	15.90	0.96	13.69	18.73
(3) Location					
HILLCBD	Feet	41386.13	19382.66	680.60	82660.94
BEAVCBD	Feet	25892.10	16281.01	967.89	84729.16
PORTCBD	Feet	50507.95	18195.82	17270.07	113661.83
(4) Amenity and disamenities					
GOLF	Square feet	225.47	1556.61	0.00	28879.63
MOUNTNVW	Binary	0.06	0.24	0.00	1.00
MINRDDIS	Feet	85.26	39.87	3.18	715.12
ONMAJRD	NA	0.07	0.25	0.00	1.00
(5) Socio-economic characteristics					
PCTWHITE	Percentage	0.93	0.05	0.54	1
MEDINC	Dollar	40877.17	10103.69	16900	76093
(6) Neighbourhood design features					
INTCON	NA	0.62	0.10	0.17	1.00
EXTCON	Feet	379.22	128.14	189.86	1116.80
SFRDNSTY	# of HHunit/acre	4.48	1.16	1.60	10.32
POPDNSTY	# of People/acre	2.28	1.79	0.07	41.30
PEDCOM	Percentage	0.26	0.21	0.00	1.00
PEDBUS	Percentage	0.38	0.26	0.00	1.00
LUMIX	Proportion	0.51	0.18	0.00	0.95
NRMIX	Proportion	0.54	0.23	0.00	0.99

Table 3 Results of hedonic price models

Variable	All samples		Urban core		Middle ring		Outer ring		Neo-traditional greenfields	
	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors
Constant	11.03*	0.1748	12.56*	0.9890	11.66*	0.3725	9.94*	0.2199	10.66*	0.2587
LOTSIZE	1.12E−05*	0.0000	1.03E−05*	0.0000	1.14E−05*	0.0000	1.45E−05*	0.0000	1.11E−05***	0.0000
FLOORSPACE	2.97E−04*	0.0000	2.51E−04*	0.0000	2.81E−04*	0.0000	3.12E−04*	0.0000	2.89E−04*	0.0000
AGE	−7.14E−03*	0.0004	−3.53E−03**	0.0012	−6.87E−03*	0.0005	−8.87E−03*	0.0006	−3.00E−03*	0.0003
AGESQUARE	5.02E−05*	0.0000			4.04E−05*	0.0000	4.48E−05*	0.0000	3.53E−05*	0.0000
INCITY	4.72E−04***	0.0003			4.20E−04***	0.0002				
SAT	1.26E−03*	0.0003					2.19E−03*	0.0004	2.78E−03*	0.0004
HILLCBD	−1.05E−07*	0.0000	−1.07E−07*	0.0000	−9.83E−08*	0.0000	−1.02E−07*	0.0000	−1.03E−07*	0.0000
BEAVCBD	6.92E−06*	0.0000	1.26E−05*	0.0000	3.46E−06**	0.0000	8.21E−06*	0.0000	6.38E−06*	0.0000
PORTCBD	−8.27E−06*	0.0000	−1.24E−05*	0.0000	−7.47E−06*	0.0000	−8.44E−06*	0.0000		
MINRD_DIS	−4.33E−04*	0.0001	−4.93E−04**	0.0002	−3.70E−04*	0.0001	−4.37E−04*	0.0001	−4.76E−04*	0.0001
ONMAJRD	−0.05*	0.0086	−0.09*	0.0200	−0.05*	0.0143	−0.04*	0.0095	−0.05*	0.0139
GOLF	5.48E−06**	0.0000					2.23E−05*	0.0000		
MOUNVIEW	0.06*	0.0105	0.03***	0.0167	0.03***	0.0176	0.08*	0.0229		
INTCON	0.27*	0.0257	0.28*	0.0824	0.26*	0.0578	0.19*	0.0404	0.32*	0.0451
EXTCON	7.41E−06*	0.0000	−1.30E−04**	0.0000	−1.04E−04***	0.0001	5.73E−05**	0.0000	6.19E−05*	0.0000
SFRDNSTY	−3.69E−03**	0.0014	−4.78E−03***	0.0028	−8.83E−03**	0.0034	−0.05*	0.0048	−2.41E−03***	0.0014
PEDCOM	0.02*	0.0044	0.02*	0.0022					0.02*	0.0045

Table 3 continued

Variable	All samples		Urban core		Middle ring		Outer ring		Neo-traditional greenfields	
	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors	Coefficient	Standard errors
PEDBUS	−0.01**	0.0037	0.06***	0.0353	−0.07*	0.0212				
LUMIX	−0.02**	0.0077					−0.04***	0.0235	−0.01*	0.0009
NRMIX	0.06*	0.0167	0.07***	0.0368	0.05*	0.0147	0.07*	0.0184	0.07*	0.0184
Count of sales	4245		926		1271		1765		283	
R SQUARE	0.75		0.72		0.71		0.72		0.70	

Note: *, **, and *** indicate significance level at the 0.001, 0.005 and 0.05 levels, respectively. Non-significant results are not presented in the table

The results are generally within expectations. We first present the results of the control variables. The physical housing attributes are related to housing price as expected. LOT-SIZE and FLOORSPACE are positively related to house price. The expected negative coefficient on AGE reveals that an older home is worth less than a newer home, and the positive coefficient of AGESQUARE indicates that the relationship between house value and house age is not linear. Public services are also capitalized into property values. As expected, INCITY is positively related to house price, reflecting the value of services provided by cities. The positive coefficient of SAT indicates that school quality matters. School districts with higher SAT scores are associated with higher sale prices. Location also matters. Negative coefficients of HILLCBD and PORTCBD indicate that housing prices fall with distance from the Portland and Hillsboro CBDs. Since the CBDs of Portland and Hillsboro are major employment centres, this was expected. The coefficient of BEAVCBD, however, is positive. This likely reflects the character of downtown Beaverton as more of an automobile-oriented retail centre than an employment centre. Amenities and disamenities affect housing prices as expected. The positive coefficient of GOLF is consistent with earlier studies. It is important to notice that GOLF is not significant in submarkets of urban core, middle ring suburbs and neo-traditional greenfields, perhaps due to the lack of variation in the amount of land devoted to a golf course in neighbourhoods in these submarkets. The positive coefficient on the binary variable MOUTNVW indicates that a view of the mountains increases property value. The coefficient of MINRDDIS has the expected negative sign, indicating that home buyers pay a premium for houses with better accessibility to minor roads. The binary variable for exposure to traffic characteristics exhibits the expected relationships. The negative coefficient of ONMAJRD indicates that home buyers pay less for houses that are within 150 feet of a major road for possible noise nuisance effects. Socio-economic variables PCT-WHITE and MEDINC are not significant, perhaps due to the lack of variation in race and income in the whole study area and in each submarket.

The neighbourhood design variables are of central interest in our study. For the whole study area, the positive coefficients of INTCON and EXTCON indicate that home buyers pay a premium for an internally connective, but externally less connective (in other words, more private) neighbourhood. The negative coefficient of SFRDNSTY is consistent with the previous market surveys which reveal that houses in neighbourhoods with low dwelling-unit density are sold at higher prices. POPDNSTY is not significant. The positive coefficient of PEDCOM indicates that consumers pay a premium for higher pedestrian accessibility to commercial uses, while the negative coefficient of PEDBUS indicates that homebuyers pay less for houses being too close to bus stops. The negative sign of LUMIX indicates that consumers do not value the mix of single-family land use with that of multi-family, commercial, industrial, public institutional and parks in the neighbourhood. The positive sign of NRMIX indicates that, when present, non-residential uses such as multi-family residential, light industrial, public institutional and neighbourhood commercial are valued more if distributed evenly in the neighbourhood.

Interesting patterns emerge when we examine the results from different neighbourhood types. Table 3 shows that the established relationships between house values and many neighbourhood design attributes are not necessarily significant everywhere in our study area. Specifically, our results show that pedestrian access to commercial stores is not a significant determinant for house values in suburban (both middle and outer ring suburbs) submarkets, that pedestrian access to bus stops is not a significant determinant for house values in outer ring suburbs and neo-traditional neighbourhoods, and that land use mix is not a significant determinant for house values in urban core and middle ring suburbs. The lack

Table 4 Results from Spatial Chow tests

Neighbourhood types	Neighbourhood types		
	Middle ring	Outer ring	Neo-traditional greenfields
Urban core	6.07*	10.65*	7.38*
Middle ring		6.72*	10.29*
Outer ring			12.53*

Note: * indicates significance level at the 0.001. Non-significant results are not presented in the table

of variation in these design features in these neighbourhoods might explain the insignificance of these variables. Alternatively, it might simply indicate that customers purchasing houses in these neighbourhoods do not value these neighbourhood design attributes of the built environment. Table 3 also shows that the magnitudes of implicit prices of neighbourhood design features differ by neighbourhood type. For example, implicit prices of both lot size and floor space are greatest in the outer ring suburbs, indicating that households purchasing in this submarket pay more for relatively larger properties than households in other submarkets do. On the other hand, the implicit price of lot size is smallest in the urban core and neo-traditional greenfields, indicating that households purchasing in the traditional and neo-traditional submarkets do not value larger properties as much as households in the outer ring suburbs do. In addition, Table 3 shows that implicit prices of increased neighbourhood internal connectivity and of enhanced pedestrian access to commercial stores are greatest in neo-traditional submarkets; that the implicit price of lowered neighbourhood density is greatest in middle ring submarket and smallest in the urban core and neo-traditional submarkets; and that the implicit prices of increased homogeneity of single-family residential uses and of increased diversity of other non-residential land uses in the neighbourhood are greatest in outer ring submarket. Furthermore, Table 3 indicates that enhanced neighbourhood external connectivity is attributed to a price premium in urban core and middle ring submarkets but to a price discount in other submarkets. It also shows that increased pedestrian access to bus stops contributes to a price premium in the urban core submarket but to a price discount in middle ring suburbs.

Although the results presented in Table 3 demonstrate that there are variations in the significance and the magnitude of the estimates associated with neighbourhood design features, they do not necessarily mean that the implicit values of these features vary significantly across the neighbourhood types. Thus we further carry out a series of Spatial Chow tests to examine whether the implicit values of the neighbourhood design features vary significantly across the traditional, neo-traditional, and suburban neighbourhood types. The results are presented in Table 4. The Spatial Chow test is an extension of the standard Chow (Chow 1960) test by Anselin (1990) and is based on an asymptotic Wald statistic.[6] On the basis of estimating hedonic housing regressions separately for each neighbourhood type, the null hypothesis is that the regression parameters do not vary between pairs of neighbourhood types and hence it is valid to pool the data for the estimation of parameters. As shown in Table 4, the Wald statistics from the Spatial Chow

[6] The asymptotic Wald statistics distributed as χ^2 with (M − 1)*K (M as the number of submarkets) degrees of freedom. In the most general form, the test for two submarkets can be expressed as a test on the null hypothesis $H_0 : g'\beta = 0$, where $\beta' = [\beta_1' \beta_2']$ is a stacked vector of all regression coefficients and g' is a K by 2K matrix $[I_k| - I_k]$, with I_k as a K by K identity matrix. The corresponding Wald test is of the form: $W = (g'b)\{g'[\text{var}(b)]^{-1}g\}^{-1}(g'b)$ where b are the estimates for the regression coefficients and var(b) is the corresponding (asymptotic) variance matrix.

Table 5 Stability of individual coefficients of neighbourhood design variables

Variables	Urban core & middle ring	Urban core & outer ring	Urban core & neo-traditional greenfields	Middle ring & outer ring	Middle ring & neo-traditional Greenfields	Outer ring & neo-traditional Greenfields
LOTSIZE		17.73*		13.19*		10.45*
FLOORSPACE	7.27*	32.73*	3.83**			
INTCON		5.40*			10.61*	12.16*
EXTCON		11.17*	7.88*			
SFRDNSTY	12.20*	25.67*	8.32*		15.93*	13.93*
PEDCOM		8.36*				7.34*
PEDBUS	20.52*	7.30*		11.14*		10.19*
LUMIX	5.90*	3.97***				
NRMIX	5.22*			3.94***		

Note: * and *** indicate significance level at the 0.001 and 0.05 levels, respectively. Non-significant results are not presented in the table

tests are all significant, indicating that the null hypotheses of parameter equality between each pair of neighbourhood types are rejected. These results provide evidence that the hedonic price function estimated for sales in each neighbourhood type is significantly different from the hedonic price function of sales in another neighbourhood type. In other words, housing submarkets are identified across traditional and neo-traditional, and suburban neighbourhood types.

To further explore whether there is a statistically significant difference between housing prices achieved by different neighbourhood design features after controlling for physical housing features, public services, location, amenities and disamenities, and socio-economic characteristics of the houses, we carry out another set of Spatial Chow tests to test the stability of individual coefficients of the neighbourhood design variables. Table 5 presents the Chow–Wald test statistics. For brevity, we do not enumerate all of the findings here. We only highlight the most important differences of interest to this study. We find that there are significant differences in the relations between sale price and most of the property and neighbourhood design characteristics as distinguished across urban core and other suburban neighbourhoods (defined by middle ring and outer ring suburbs). We also find that, across suburban and neo-traditional neighbourhoods, differences in the relations between sale price and neighbourhood connectivity and single-family dwelling unit density are consistently significant. Across outer ring suburbs and neo-traditional neighbourhoods, significant differences are also found in the relations between sale price and lot size and pedestrian access to commercial stores and bus stops. Across urban core and neo-traditional submarkets—the two similar neighbourhood types in neighbourhood design—significant differences are found in the relations between sale price and house size, neighbourhood external connectivity and single-family dwelling unit density.

5 Caveats and future directions

Before we draw any conclusions from this study, it is necessary to note several limitations of our research. First, this paper only refers to the owner-occupied single-family segment of the housing market. The differences between sale price and neighbourhood design features across neighbourhood types might be even more significant in the multi-family residential market. Due to data limitations, we were not able to carry out the analysis including the multi-family segment of the market.

Second, this analysis is based on a cross-sectional selection of neighbourhood types in our study area. However, the variation in the relationship between sale price and neighbourhood design features might change over time due to changing demographics and/or changing tastes of households (Myers et al. 2002). While it is necessary to carry out a time series analysis of housing market segments on the basis of neighbourhood design features, we must leave this for future exploration.

Third, our results apply *only* to Washington County in the Portland metropolitan area. The exclusion of the eastern part of the metropolitan area raises concern because some households may consider housing in the omitted area to be a close substitute for housing in the included area. Moreover, Portland is unique in its urban growth management instruments which may mean it is not representative of other places in the United States. Therefore, the results we have presented here might not be applicable to other city markets. Comparative studies could be carried out to compare submarkets of neighbourhood design across cities in different parts of the world.

Fourth, it is notable that we do not include socio-economic characteristics in classifying neighbourhood types (see Appendix for more information). However, it is possible that these neighbourhood features are correlated with socio-economic characteristics in the neighbourhoods. We have controlled for the socio-economic characteristics of the neighbourhoods using both income and racial composition variables in the hedonic price regression analyses. Thus, a varying magnitude of implicit prices of neighbourhood design attributes across neighbourhood types is indeed associated with neighbourhood features. Nevertheless, a holistic method integrating both socio-economic characteristics and built environment features should be developed in future studies.

Finally and most importantly, the purpose of this research is to explore whether the implicit values of neighbourhood design features are significantly different across neighbourhood types. Identifying who lives in each housing market segment and understanding why the households are selecting their neighbourhood type (for example, suburban vs. traditional or neo-traditional) are beyond the scope of this research. Additional survey data on demographic characteristics of the residents of different submarkets and those residents' preferences for neighbourhood design are needed to answer these questions. In essence, a future analysis would seek to determine whether different households are distinguished from each other by not only residential site location but also by different preferences for neighbourhood design.

6 Conclusions

The purpose of this research is to examine whether the relationship between neighbourhood design features and housing prices is different across traditional, neo-traditional, and suburban neighbourhood types, using data from Washington County, Oregon. The traditional urban core, neo-traditional greenfields, and two suburban (middle ring and outer ring suburbs) neighbourhood types are distinct in their neighbourhood design features. The urban core submarket has many traditional features such as grid street networks, small lots, high density, mixed land uses, and accessible bus services. The neo-traditional greenfields have modified grid and connective street networks, high density, a moderate level of bus services, and a limited level of land use mixture. The middle and outer ring suburbs, differing from each other mainly in time of development and amount of open space, contain relatively large lots of a uniform size and shape, curvilinear and wide streets, winding cul-de-sacs, homogeneous single-family land use, and a general lack of mixed land uses and transit services.

Based on the results we obtained from our multiple-step methodology, we find that some of the neighbourhood design features are valued differently across neighbourhood types. Our results indicate that several traditional design virtues are not valued significantly in suburban submarkets. For example, pedestrian-approachable commercial stores are not significant determinants of house prices in both middle and outer ring suburbs; accessible bus services are not substantially valued in outer ring suburbs and newly developed neo-traditional neighbourhoods. It is noteworthy that the insignificance of these design traits can be explained either by the indifference to the features of the consumers buying in those submarkets, or by the lack of variation of these design features in these submarkets. Furthermore, the varying magnitude of implicit prices of neighbourhood design attributes across neighbourhood types reveals interesting findings. Traditional design merits such as increased neighbourhood internal connectivity and enhanced pedestrian access to commercial stores are valued more in either traditional or neo-traditional submarkets. On the other hand, conventional suburban features such as larger lots and houses, lower density, and homogeneous single-family residential land use are valued more by consumers purchasing in suburban submarkets, either the middle or the outer ring suburbs. Finally, the research also identifies several design attributes that are having reverse effects on house values across submarkets. Specifically, we find that enhanced neighbourhood external connectivity (in other words, more integrated and less isolated neighbourhoods) and increased pedestrian access to bus stops are contributing to a price premium in urban core submarket but to a price discount in middle ring suburbs.

All these findings clearly suggest that the implicit prices of traditional, neo-traditional, and conventional suburban neighbourhood design attributes vary across different types of urban built environment. Seemingly, the variance of implicit prices across neighbourhood types is a result of the conditions of supply and demand for neighbourhood design features prevailing in each housing market segment. That is to say, the implicit prices paid for specific housing and neighbourhood attributes in different submarkets reflect differences in demand and/or supply considerations (Day 2003). If the supply of different neighbourhood design attributes is the same in all neighbourhood types, one could conclude that in the submarket with the greatest implicit price for a neighbourhood feature, there is greater demand for that neighbourhood feature. Alternatively, if the demand for different neighbourhood features is the same in all neighbourhood types, the availability of a neighbourhood design feature could be limited in the submarket with the greatest implicit price for that neighbourhood feature (Day 2003). Without further exploration, we won't be able to conclude if high implicit prices of neo-traditional design features, for example, are due to expanded demand or deficient supply. We suspect that the differences between neighbourhood features and implicit prices across submarkets are possibly the result of demand considerations. In other words, the demand or preferences for neighbourhood design factors may vary among the consumers purchasing in different submarkets. If this were so, promoting only one type of neighbourhood design may not meet the preferences of all households. An examination of this and of alternative explanations calls for future analysis.

Appendix: Classifying neighbourhood types

We have identified four different urban neighbourhood types: urban core neighbourhoods, middle ring suburbs, outer ring suburbs, and neo-traditional greenfields. We combine two approaches—statistical and a priori procedures—to identify these neighbourhood types.

To define different neighbourhood types using statistical methods, we use GIS data from Portland Metro's Regional Land Information System (RLIS). These data include (1) parcel based property (taxlot) data such as: year the structure was built, land use type, lot size, and floor space; (2) street network centrelines; (3) major transit stations and lines; (4) parks, open space and other recreational land uses; (5) tree canopy; (6) political and planning boundaries, such as county and city boundaries and urban growth boundaries; and (7) aerial photographs.

To classify neighbourhood types for all neighbourhoods, which are defined by 186 census blockgroups, we compute 16 urban form measures developed by Song and Knaap (2004) to characterize neighbourhood design. All the calculations were computed using ARCInfo and ArcView with data from Metro's RLIS. Definitions of these measures are shown in Table A1. To measure street network design, we include the number of different types of street nodes, the size of street blocks, the lengths of cul-de-sacs, and the distance between points of access into the neighbourhood. To capture house characteristics, we include the size of lot and dwelling. To quantify neighbourhood density, we offer two

Table A1 Definition of 16 variables of neighbourhood design

Variable	Definition
INTCON	Number of street intersections divided by the number of intersections plus the number of cul-de-sacs; the higher the ratio, the greater the internal connectivity.
BLOCKSIZE	Median value of perimeter of the blocks in a neighbourhood; the smaller the perimeter, the greater the internal connectivity.
CulDeSac	Median length of cul-de-sacs; the shorter the cul-de-sac, the greater the internal connectivity.
EXTCON	Median distance between Ingress/Egress (access) points in feet; the greater the distance, the poorer the external connectivity.
LOTSIZE	Median lot size of single-family dwelling units in the neighbourhood; the smaller the lot size, the higher the density.
FLOORSPACE	Median floor space of single-family dwelling units in the neighbourhood; the smaller the floor space, the higher the density.
SFRDNSTY	Single-family residential (SFR) dwelling units divided by the residential area of the neighbourhood; the higher the ratio, the higher the density.
POPDNSTY	Number of households divided by area of the neighbourhood; the higher the ratio, the higher the population density.
COM, PUBLIC, MFR, INDUSTRIAL	Acres of commercial, public, multi-family residential, and industrial land uses, respectively, in the neighbourhood divided by number of housing units; the greater the ratio, the greater the mix of that type of land use.
PEDCOM	Percentage of SFR units within one quarter mile of commercial uses; the greater the percentage, the greater the pedestrian accessibility.
PEDBUS	Percentage of SFR units within one quarter mile of bus stops; the greater the percentage, the greater the pedestrian accessibility.
PARK	Acres of park in the neighbourhood divided by number of housing units.
CANOPY	Acres of the area with tree canopy in the neighbourhood divided by number of housing units.

measures: single-family residential (SFR) dwelling unit density and population density. To compute the level of mixed land uses in a neighbourhood, we keep track of the amount of commercial, public, multi-family residential (MFR), and light industrial land uses. To estimate pedestrian walkability, we include the percentage of single-family homes that are within one-quarter mile network distance (suggested by Duany and Plater-Zyberk 1992) of commercial uses and bus stops. Finally, to approximate the amount of open space in a neighbourhood, we include the acres of public parks and the area with tree canopy. Previous studies have proved that this set of variables measuring neighbourhood design can capture meaningful differences between different neighbourhoods (Song and Knaap 2003, 2004).

We then factor the above computed 16 measures of neighbourhood design into fewer dimensions, and then use cluster analysis to classify neighbourhood types statistically. We use factor analysis, a technique for data reduction, to help us understand the dimensional structure of our variables. Some of the 16 measures of neighbourhood design are highly correlated: for example, the distribution of cul-de-sacs is highly correlated with the distribution of large blocks. We therefore condense these variables into a smaller set of variables to remove the correlation in the data. Seven dimensions (factors) are extracted. The results are presented in Table A2. The variables in Table A2 are listed in the order of the size of their factor loadings sequentially for each factor. The extracted factors reproduce about 75% of the total variation. The last row of Table A2 presents the percent of the total variation accounted for by each factor. Principal component analysis for extraction and Varimax with Kaiser Normalization as rotation method in the factor analysis are used since this combination explained the most variation in the data. Varimax is used to maximize the variance of the squared loadings. Table A2 shows that the first factor reflects

Table A2 Results of factor analysis

Variable	Connectivity	Pedestrian accessibility	Density	Land use mix	House character	Commercial	Park
INTCON	−0.904	0.006	0.035	0.051	−0.035	0.019	0.005
CulDeSac	0.675	0.450	0.318	−0.240	0.157	−0.189	0.091
EXTCON	0.557	−0.253	0.126	−0.119	0.454	−0.369	−0.179
BLOCKSIZE	0.114	−0.763	−0.078	−0.098	0.153	−0.164	0.072
PEDBUS	−0.113	0.740	0.263	0.128	0.128	0.131	−0.221
MFR	−0.014	0.146	0.760	−0.042	0.072	−0.202	0.023
POPDNSTY	0.283	0.252	0.746	0.024	−0.093	0.005	−0.055
SFRDNSTY	−0.054	−0.021	0.720	−0.107	0.030	0.068	−0.011
PUBLIC	0.179	0.030	0.223	0.845	−0.012	−0.072	0.044
INDUSTRIAL	−0.004	0.155	0.015	0.711	0.026	0.068	0.117
LOTSIZE	−0.378	0.046	0.006	0.062	0.661	−0.218	−0.397
FLOORSPACE	−0.048	0.107	0.047	−0.054	0.614	0.109	−0.081
PEDCOM	−0.020	−0.082	0.212	0.012	−0.023	−0.696	−0.018
COM	0.023	0.579	0.085	−0.026	−0.250	−0.597	0.072
PARK	0.211	0.467	−0.010	−0.072	0.199	−0.161	−0.671
CANOPY	0.152	−0.322	0.070	0.169	−0.241	0.082	−0.594
% Variance	0.154	0.141	0.128	0.086	0.084	0.082	0.078

the dimension *Street Connectivity*. Factor loadings indicate that shorter cul-de-sacs and higher internal and external connectivity contribute to a smaller value of factor 1. The second factor includes *Pedestrian Accessibility* variables: higher pedestrian access to bus stops and smaller blocks contribute to a larger value of factor 2. The third factor includes *Density* variables: more multi-family residential uses within the neighbourhood and higher population and single-family residential dwelling unit density contribute to a larger value of factor 3. The fourth factor reflects the level of *Land Use Mix*: more industrial and more public land uses lead to a larger value of factor 4. The fifth factor relates to *House Characteristics* and shows that larger lots and houses contribute to a larger value of factor 5. The sixth factor reflects the level of *Commercial Uses*: higher pedestrian access to commercial stores and more commercial land uses contributes to a smaller value of factor 6. The last factor relates to the *Natural Environment*: more area of tree canopy and more parks contribute to a smaller value of factor 7.

Next, we perform cluster analysis, a method of combining observations into groups based on their similarity within a set of predetermined characteristics, to group neighbourhoods into neighbourhood types. K-means cluster analysis is performed on the seven factor scores derived from the previous step in such a way that each neighbourhood type is internally as similar as possible but externally dissimilar to other neighbourhood types. The best clustering solution, based on the interpretability of the results and associated cluster statistics, is found to be a six-cluster solution. The values of the cluster centroids, which indicate the performance of each neighbourhood type on each dimension (factor), are presented in Table A3. Six neighbourhood types emerge from the analysis and they are: rural neighbourhoods with dispersed homes, rural neighbourhoods with clustered properties, urban core neighbourhoods, middle ring suburbs, outer ring suburbs, and neo-traditional greenfields. We only focus on four urban neighbourhood types in the hedonic price regressions since we are only interested in examining housing product differentiation in an urban housing market.

We then verify the boundaries of urban core, middle ring suburbs, outer ring suburbs, and neo-traditional greenfields that resulted from the statistical method by inquiring among local real estate agents. The consistency between the statistically determined boundaries and the perceived market areas by real estate agents confirms the reliability of the classification of neighbourhood types.

Table A3 Cluster centroid values for each neighbourhood type

Variable	Type 1 Rural	Type 2 Rural community	Type 3 Urban core	Type 4 Middle ring suburbs	Type 5 Outer ring suburbs	Type 6 Neo-traditional greenfields
Connectivity	−0.1919	−0.0982	4.9811	−0.131	0.1608	0.7614
Pedestrian access	−0.1599	−0.7427	1.2949	0.9513	1.0629	1.2342
Density	−0.161	−0.0301	0.0815	0.0465	0.0654	2.0848
Land use mix	−0.2403	−0.0508	0.9047	0.1402	0.0962	4.4849
House character	3.2918	3.4192	−0.6365	0.8684	0.8126	−0.2621
Commercial	−0.973	−0.7666	1.5912	0.2089	−1.6712	0.4941
Park	0.1176	0.1936	0.0154	−0.1989	0.2256	0.1033

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