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The spatial planning of housing and urban green space: A combined stated choice experiment and land-use modeling approach

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ABSTRACT

Urban green space (UGS) is receiving increasing attention as a means to make cities better adapted to climate change and to create high-quality living environments for citizens. The spatial planning of UGS generally asks a trade-off between optimizing land-use and accessibility characteristics which may differ between housing types. In this paper, we use a stated choice experiment to estimate residential location preferences related to neighborhood land-use, UGS and accessibility characteristics in the framework of a land-use model. A national sample of 394 Dutch homeowners participated in the experiments and mixed logit models were estimated by housing type distinguishing detached, row houses and apartments. The estimation results show that trade-offs made between a green neighborhood and accessibility to urban amenities tend to differ between the housing types. The estimates are used as parameters in a housing land-use allocation model. An application of the model to a residential area development problem shows that creating green buffers along road infrastructure is the most beneficial way of allocating UGS considering the housing value for residents. The application further shows that apartments benefit more strongly from UGS in the neighborhood than from high accessibility of urban amenities compared to detached and row houses. Finally, we find that the optimal spatial allocation of UGS depends on whether maximizing housing market-value or residents' utility is the prime objective.

1. Introduction

Urban green space has large potential to mitigate negative effects of climate change related to hydrology, temperature, and extreme weather (Gonçalves et al., 2019; Locatelli et al., 2014; Nielsen et al., 2017; Zölch et al., 2016). Therefore, in order to adapt to climate change, cities widely consider spatial policies aimed at improving urban green infrastructures (Yang and Wang, 2017; Zhang, Murray, and Turner, 2017). However, urban green space has to compete with other land-use demands, such as housing and commercial activities. Using land for urban green space (UGS) development may not be attractive for real estate developers who aim to maximize profit (Beuschel and Rudel, 2010). Reserving land for urban green generally means building in smaller densities which may negatively affect the value of development. This loss is counterbalanced at least to some extent with potential gains in the form of positive externalities of green.

Land-use allocation models offer a useful tool to investigate these trade-offs and find suitable solutions for land-use allocation problems (see Haque and Asami, 2014). These models generally consider the allocation of a wide range of land-use types, including industrial, commercial, housing and nature, simultaneously. In this study, we focus on housing area development problems and address the question of how the interests of different stakeholders including residents and commercial housing developers can be balanced in spatial solutions for housing and UGS demands. Given this focus, land-use models specifically focused on spatial allocation of housing demands are relevant here. The housing land-use model developed by Arentze et al. (2010) is such a model that we will use as framework in the present study.

The empirical estimation of land-use allocation models is a critical factor in the application of these models. Traditionally, hedonic price analysis based on housing transaction data is used to estimate homeowners' willingness-to-pay for particular location and structural attributes of a dwelling (Brady and Irwin, 2011). Alternatively, utility parameters in land-use models have been estimated empirically using land-use data and map comparison methods (Van Vliet et al., 2013). These revealed preference approaches have however a well-known limitation. The presence of unobserved spatially correlated variables, generally, restricts the ability to estimate unbiased utility parameters of

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a location suitability function. The stated choice experiment is an alternative method for collecting the data that can avoid this problem. Using orthogonal or nearly orthogonal designs, the correlations between variables are avoided so that the separate effects of (spatial) variables on utility can be identified (Timmermans et al., 1994; Glumac and Islam, 2020).

The goal of the present study is to show how the stated choice experiment can be used to estimate utility parameters and derive the willingness-to-pay values to be used in a housing land-use model (HLM). To our knowledge, the stated choice experiment has not been used before for this purpose. We present a design of a stated choice experiment with special attention for UGS. The experiment is implemented in an online survey to collect data involving a sufficiently large national sample of homeowners in the Netherlands. The estimates are used to specify the location suitability function of an HLM. To demonstrate the approach, we apply the HLM model to a housing area development problem.

The rest of the paper is structured as follows. First, the next section provides a review of existing literature on the design and use of stated choice experiments in housing. Next, the third section explains the methodology of the stated choice experiment and the housing land-use model (HLM). In the sections that follow, we then discuss the results of the experiment and an application of the resulting HLM in a housing development case study. Finally, in the concluding section, we summarize the major conclusions and discuss remaining problems for future research.

2. Literature review

The Stated Choice Experiment (SCE) is a technique to estimate preferences of individuals for products or services that is widely used in housing preference research as well as other fields of consumer behavior research. The theoretical framework on which the method is based is random utility theory, which states that individuals when faced with a choice (e.g., housing alternatives) compare the choice alternatives on relevant attributes (e.g., size, price, number of rooms) and choose the alternative that maximizes their utility. In an SCE, respondents are presented hypothetical choice alternatives which are varied in terms of a number of attributes based on a statistical attribute design. Respondents are asked for each choice set to choose the alternative they prefer. Based on the choice data thus obtained, utilities for attribute levels can be statistically estimated in the framework of a discrete choice model (Louviere et al., 2000). Willingness-to-pay values can be derived from estimated utilities provided that price level is included as an attribute of the choice alternatives. In this section, we will review existing literature related to stated choice analysis in housing research.

In housing research, applications have focused on a variety of specific topics such as energy renovation (e.g., Tiellemans et al., 2022, Ossokina et al., 2021), household decision making (e.g., Molin et al., 2002), senior housing (e.g., De Jong et al., 2018), student housing (Verhetsel et al., 2017), and housing in developing countries (Del Mistro, A. Hensher, 2009). For the present research especially relevant are studies that have used the stated choice experiment to estimate preferences for location and neighborhood attributes in housing location choice of households. We discuss these below.

Several studies have used stated choice experiments to derive valuation of accessibility-related location attributes. Aung and Vichiensan (2019) found that accessibility to work or school and the quality of the neighborhood have significant influence on housing value in addition to structural dwelling characteristics. Kim (2006) showed that the willingness-to-pay (WTP) for amenity-related attributes strongly depended on income level. Wu and Zhao (2015) investigated WTP for accessibility to the city center and found a similar increasing effect of income framed as housing affordability on WTP. Tillema et al. (2010) analyzed the impact of travel costs on residential location choice depending on scenarios of road pricing (toll roads). Ossokina et al. (2020) used the stated choice experiment to define the best living concepts for senior housing and Ossokina and Arentze (2022) examined reference dependency in housing choice.

The above mentioned studies focused on location attributes related to accessibility. Other SCE studies had a specific interest in neighborhood characteristics. Torres et al. (2013) estimated valuation for a range of neighborhood and structural characteristics of the dwelling and found that neighborhood is an important factor in housing location decisions. Several SCE studies particularly focused on measuring preferences for urban green space in the neighborhood. Tu et al. (2016) found that green space in the neighborhood influences residents' WTP due to the value a green environment has for both recreation and scenic view. Dongen and Timmermans (2019) varied types of urban green as part of landscape design in an SCE and found that preferences for a neighborhood differ considerably depending on the specific intrinsic qualities of the green present. They found that trees have the strongest influence, despite the fact that grass is often favored by local governments, and that vertical green has the smallest effects on residential preferences. In terms of land-use, Olitsky et al. (2021) considered accessibility to a mix of commercial land-use and public facilities and found a positive WTP-value for such mixed land-use in the neighborhood.

As the above review indicates, SCE studies on housing location choice shows that both accessibility and neighborhood characteristics have a significant impact on housing location choice and WTP. Despite the extensive work in this area, existing studies have two important shortcomings for the purpose of estimating the utility parameters of a HLM. First, applications of SCE's that consider both accessibility and neighborhood factors are largely missing. An exception is Wang and Li (2006) in the Chinese context, who propose and apply a comprehensive SCE design including both accessibility and neighborhood factors. Their results underline the importance of both types of attributes in people's housing choices. Second, existing studies have not taken into account possible heterogeneity in preference parameters related to different housing types (e.g., apartments, row houses, and detached houses) that constitute the different housing land uses in an HLM.

3. Methodology

In this section, we first describe the stated choice experiment designed to estimate the land suitability function for a HLM and, next, we introduce the HLM used in the application presented in the next section.

3.1. Stated choice experiment

Design of a stated choice experiment starts with the selection of the attributes on which presented choice alternatives, in this case residential locations, are varied. Based on the literature review and the focus on UGS, eleven attributes were selected. The specification of the levels of the attributes is tailored to the spatial structure of urban areas in the Dutch context (e.g., typical distance ranges and neighborhood characteristics). Table 1 shows the attributes and their levels used in the experiment. They are grouped into attributes related to the neighborhood environment and attributes related to accessibility of locations. The neighborhood attributes include open green area, greenery along streets, presence of a school complex, and the amount of road traffic. A school complex is taken here not for its specific characteristics but as an instance of a public, non-housing land-use that that may be mixed with the residential land-use in neighborhoods. The accessibility attributes include distances to the city center, shopping center, entertainment, train station, and green park. The distances are expressed in travel time because travel time aligns with individuals' real-world experiences and perceptions and people often make choices based on how long it takes to get somewhere rather than the actual distance (Arentze and Molin, 2013).

For each attribute, three levels are specified representing a low,

Table 1
Attributes and attribute levels used in the stated choice experiment.

Sub-experiment 1 Attribute	Level 1	Level 2	Level 3
Open green area	No open green area (fully built-up, park / waterbody covers less than 10 %)	A small green space (park / waterbody covers about 25 %)	A larger green space (green park / waterbody covers about 50 %)
Greenery along the streets	No greenery - only sidewalks and buildings	Some greenery - a line of trees lining the streets	A lot of green - wide streets with many trees lining the streets
School complex (public building)	Exclusively homes (all residential)	A small school complex that takes up about 25 % of the area	A large school complex that takes up about 50 % of the area
Amount of traffic	No through road with car traffic	The house is located on a main road with some car traffic	The house is located on a main road with a lot of car traffic
Price	10 % lower	About the same	10 % higher
Sub-experiment 2 Attribute	**Level 1**	**Level 2**	**Level 3**
Distance to CBD	About 10 min. walking	About 10 min. cycling	About 20 min. cycling
Distance to shopping center	About 5 min. walking	About 10 min. walking	About 15 min. cycling
Distance to entertainment	About 5 min. walking	About 15 min. walking	About 15 min. cycling
Distance to train station	Within 10 min. walking	Within 15 min. cycling	More than 15 min. cycling
Distance to green area	Within 10 min. walking	Within 10 min. cycling	More than 10 min. cycling
Price	10 % lower	Equal to the current	10 % higher

middle and high quality. For instance, for the green attribute, the levels are no open green area (fully built-up area with green covering less than 10 %); small area of green space (covering about 25 %), and larger area of green space (covering about 50 %). It is noted that the open green area attribute refers to nature-like land uses that possibly may include a water body such as a pond. The price levels are pivoted around the market value of the current dwelling of the person to make sure that offered alternatives fall within a price range that is realistic for the respondent. Given the target group focused on, only persons who currently are living in a privately owned dwelling were invited to participate.

Including all attributes in a single experiment would result in a choice task that is cognitively too demanding for respondents (Arentze et al., 2003). Therefore, following the approach of Arentze and Molin (2013), Torres et al. (2013), and Ossokina et al. (2020), the two groups of attributes were exploited in two separate choice experiments. The housing price attribute was used in both experiments. Given the presence of a bridging attribute, the choice data obtained across the two experiments can be pooled for estimation. For each experiment (neighborhood environment and accessibility), a fractional factorial design was used satisfying the conditions of orthogonality and attribute level balance that enable the unbiased estimation of the main effects of attributes. The designs specify 16 and 18 attribute profiles for the neighborhood and accessibility experiment, respectively. In both experiments, choice sets consisted of two housing choice alternatives. They were created by randomly drawing attribute profiles from the discussed designs.

In each choice experiment, respondents were presented randomly five choice sets. The respondents were asked to imagine that the choice alternatives presented all concern the same housing type (apartment, row house or detached house) as they currently own. Respondents were further instructed to imagine that the presented alternative dwellings do not differ regarding structural attributes but only with respect to the location attributes presented. The sample of participants drawn for the experiment was stratified such that (approximately) equally sized groups of apartment, row-house, and detached-house owners participated in the experiment. In this way, we were able, given a sufficiently large sample size, to estimate separate discrete choice models for the housing segments, as required for the HLM.

We estimate the utility parameters in the framework of a random-parameters mixed logit model. The mixed logit (ML) model is an extension of the more basic multinomial logit (MNL) model; it allows for heterogeneity in tastes between individuals. By taking heterogeneity into account the parameters can be estimated more accurately (Train, 2009). In the model, the utility individual i would obtain from dwelling alternative j at choice observation t is:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \quad (1)$$

where V_{ijt} is a structural component and ε_{ijt} a random component of the utility. The structural component is specified as:

$$V_{ijt} = \sum\nolimits_n (\beta_n + \xi_{ni}) X_{jtn} \quad (2)$$

where X_{jtn} represents the value of choice alternative j at choice observation t on attribute n, β_n is an average marginal utility assigned to that

Neighborhood environment	Option 1 (Dwelling 1)	Option 2 (Dwelling 2)
The built environment	All residential	There is small school complex site
Presence of greenery along the streets	There is no greenery – only sidewalks and buildings	There is some greenery – a line of trees lining the streets
Presence of open green area	There is no open green area	There is no open green area
The amount of traffic	There is no through road with car traffic	The house is located on a main road with a lot of car traffic
The price of the house compared to what you have now	10 % lower	10 % higher

Please choose the appropriate response to each item:

	Which option do you prefer ?			Would you prefer this living situation to your current living situation?	
	Option 1	Option 2		Yes	No
Your choice:	○	○		○	○

Fig. 1. Print screen of a choice set.

attribute and ξ_{ni} is an individual-specific random component that captures individual i's deviation from the average valuation for attribute n.

Based on the estimates of the β-parameters, WTP-values for each attribute n are derived as $WTP_n = \beta_n/\beta_0$, where β_0 is the parameter of the price attribute. Note that since in the experiment, the price attribute is defined in relative terms (percentage increase or decrease compared to the current dwelling), the WTP values derived from these parameters are also expressed in relative terms (percentage price change).

3.2. The housing land-use model

As a basis for the application, we use the housing land-use model (HLM) described in Arentze et al. (2010) and used in planning scenario studies by Katoshevski-Cavari et al. (2010), (2011), (2014). The HLM seeks to find the spatial allocation of a set of given housing demands that maximizes a suitability function. In this model, the plan area is represented as a regular grid of cells where each cell corresponds to a land lot with a particular land-use.

A suitability function computes for each undeveloped cell a suitability score for each possible land-use development in that cell, taking into account the current land-uses in other cells. The total suitability of a land-use plan equals the sum of suitability scores based on the assigned land-uses across all cells. The system applies an iterative land-use allocation procedure. In this procedure, an initial allocation of land-use demands is incrementally improved by making swaps of land-uses between any two cells if that increases the total suitability value. The process of swapping continues until no further swaps are possible that increase the suitability. For details of the algorithm and its properties, readers are referred to the original publications. The suitability of a particular housing development in a particular cell is defined as:

$$Z_{ijk} = F_k \bullet V_{ijk} \tag{3}$$

where Z_{ijk} is the utility of developing housing type k in cell ij, V_{ijk} is the utility of a dwelling of type k at location ij and F_k is a housing density (number of dwellings of type k per cell).

3.3. Implementing the estimated utilities in the HLM

The attributes used in the SCE can be mapped on the neighborhood and accessibility variables used in the suitability function. Using one-hectare cells, the neighborhood of a cell (8 adjacent cells) roughly corresponds to the size of a neighborhood area in the Netherlands, so that the variables in the HLM and attributes in the SCE refer to the same spatial unit. Since the attributes match the setting the HLM works with, the parameters of the ML models, given proper estimations, can be used to define the utility function in the HLM (V_{ijk} in Eq. 3). There are however two issues that require attention. First, the discrete specification of the attributes in the ML models does not match with the HLM. There are two possible ways to overcome this, namely 1) estimating a single parameter for the attribute assuming a linear effect of the attribute value and 2) estimating a parameter for each attribute level and using interpolation to determine the actual value when needed in the HLM. Since UGS is a dynamic land use in the HLM, the attribute can vary in a continuous manner. Therefore, for the open green space attribute the first method is used (assuming a linear effect) and for the other attributes which are static in the HLM model, the second method is used (discrete utility values with interpolation).

Second, the values of beta parameters from Eq. (2) cannot be used directly, because the scale of utilities cannot be compared between models estimated for different housing types (apartments, row, detached). Reason is that the scale depends on the size of the error variance which may differ between models (Bradley and Daly, 1994). The WTP-values do not have this restriction as they are computed as ratios of the utility parameters and, therefore, can be compared across the models. Therefore, the WTP-values rather than the basic beta parameter estimates are used.

We will exploit two specifications of the WTP in two alternative scenarios: a WTP-value defined in relative terms (percentage increase of price) and a WTP-value defined in monetary terms (euros). For the latter, the WTP-values derived from the utility estimates are multiplied by an average price level for the dwelling type under consideration. This means that for a same value of WTP in relative terms, a more expensive dwelling type (e.g., detached compared to row) results in a higher WTP in absolute terms. The two scenarios – the use of absolute versus relative values of WTP – thus, differ in terms of whether or not the price is used as weight. Whereas the relative values better represent the utility of residents, the absolute values are more relevant when the goal is to maximize the utility for commercial developers (market value). To some degree, the two scenarios can be seen as differentiating between the public welfare and the commercial market value objective.

4. Analysis of housing location preferences

4.1. Stated choice experiment data

The questionnaire used to collect the data consists of two parts: questions to retrieve socio-demographic and housing data and the two stated choice experiments. It was administered online in June 2021. A random sample of 384 homeowners from a national panel in the Netherlands participated and completed the questionnaire. As intended, the sample was distributed approximately equally across the three housing types, apartment ($N = 137$), row houses ($N = 129$) and (semi-) detached ($N = 118$). Fig. 2 shows the distribution of the respondents across the country.

4.2. Sample characteristics

Descriptive statistics of the sample by housing-type segment are given in Table 2. The sample is fairly evenly distributed across gender groups in each of the three segments. As expected, the 45–64 age group is the largest age group in all three segments. As for household composition, the distribution differs strongly between the segments with substantially lower number of households with children in the apartment segment, which is also clearly reflected in the differences in distributions of household size (number of persons). The largest net income categories are €1751 to €2400 in the apartment (29.9 %) and more than €3650 in the row (38.8 %) and detached (45.8 %) segments. In terms of both working status and education level, the distributions in the

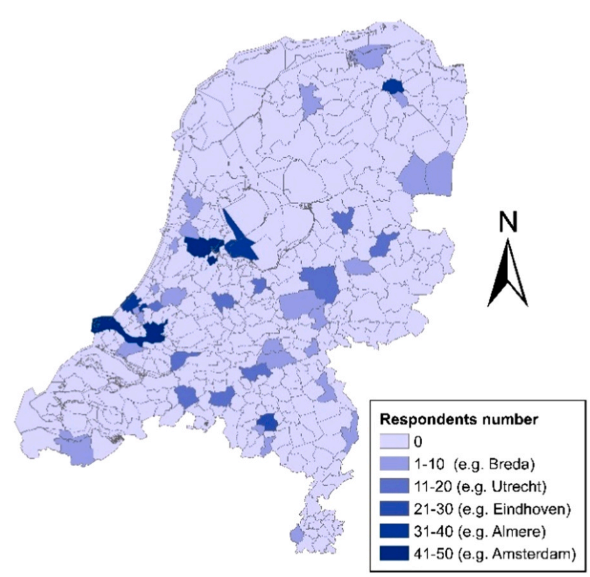

Fig. 2. The distribution of the respondents across the Netherlands.

Table 2
Sample descriptives by segment ($N = 137$ for Apartment, $N = 129$ for Row house and $N = 118$ for Detached).

Attributes	Description	Apartment %	Row house %	Detached %
	Male	52.6	45.7	56.8
Gender	Female	47.4	54.3	43.2
	<25	0.7	8.5	5.9
	25–44	37.2	23.3	22.0
	45–64	40.8	52.8	48.3
Age	65+	21.2	15.5	23.7
	Alone	42.3	9.3	5.9
	with partner	44.5	34.9	45.8
	with partner and child(ren)	10.9	43.4	40.7
Household composition	with parents	0.7	8.5	5.9
	Other	1.5	3.9	1.7
	1	40.9	9.3	5.9
	2	47.4	36.4	48.3
	3	8.8	26.4	16.1
Size of the household (number of persons)	4	1.5	18.6	23.7
	>4	1.5	9.3	5.9
	< € 1750	7.3	0.8	5.1
	€ 1751–2400	29.9	10.9	6.8
	€ 2401–3000	14.6	20.9	11.0
	€ 3001–3650	13.9	11.6	21.2
	> € 3650	23.4	38.8	45.8
Household net monthly income	I do not want to say	10.9	17.1	10.2
	Full time	41.6	41.9	39.0
	Part-time	30.6	34.1	28.8
Work status	No paid work	27.7	24.0	32.2
	Primary and Secondary	19.1	28.7	18.7
	Middle-level applied education	21.9	24.0	21.2
	Higher professional education	39.4	34.9	38.1
Educational Level	University	19.7	12.4	22.0
	< € 150,000	6.6	0.8	0.0
	€ 150,001- € 200,000	19.0	1.6	3.4
	€ 200,001- € 250,000	20.4	16.3	10.2
	€ 250,001- € 300,000	11.7	20.9	9.3
	€ 300,001- € 350,000	10.9	19.4	11.9
Market value of your dwelling	€ 350,001- € 400,000	11.7	17.8	13.6
	>€ 400,000	19.7	23.3	51.7

segments show similar tendencies. Finally, in terms of the market value of the dwelling, the distributions show a clear tendency, as expected, of more expensive dwellings in the detached segment and less expensive dwellings in the apartment segment with the row house segment in-between.

4.3. Results of model estimations

The mixed logit model was estimated for each of the three housing types. To estimate the mixed logit models, a normal distribution was assumed for each random parameter. To obtain stable estimates, two thousand Halton sequences were used.

Table 3 shows the goodness-of-fit statistics of the estimated models. The adjusted rho-square values for the estimated models are 0.24, 0.21, and 0.26, respectively. As the values are larger than 0.2, the goodness-of-fit of each model is satisfactory (McFadden, 1973).

Table 4 shows the estimation results for each model in detail. Using dummy coding, a parameter is estimated for each level of each attribute. The first (lowest) level is taken as the base for every attribute, except for

Table 3
Statistics of the estimated mixed logit models.

	Apartment	Row	Detached
N	1370	1290	1180
Rho-square adjusted	0.24	0.21	0.26
LL null model	-949.61	-894.16	-817.91
LL final model	-711.81	-689.75	-588.00

the price attribute. For the price attribute the middle level is the most natural choice of the reference. For open green area a single parameter is estimated which represents the linear utility effect of the percentage of green in the neighborhood.[2] A linear parameter matches the HLM where UGS is a dynamic land-use and hence can vary on a continuous scale. The identification of random parameters was based on a sequential procedure, to avoid overfitting problems. In this procedure, the parameters are included one at a time as random parameter in the model and kept as random parameter only if the standard deviation turns out to be statistically significant. We will now discuss the results.

The constant represents a base utility of the first alternative in the choice set. Since the order of alternatives is random, the statistically significant positive value of the constant indicates that there is a first-option bias. This bias is the consequence of a tendency of people to choose the first alternative in the choice set and is well-known in the literature (Zhao et al., 2022). By including this constant as a parameter, the model can control for this bias. The estimates of remaining parameters represent actual preferences in choice behavior and will now be discussed.

We first consider the neighborhood environment attributes. The parameter estimates for open green space and green along streets show, as expected, that homeowners assign a positive value to the presence of urban green in all three segments. The presence of a school complex is evaluated as negative if it covers a relatively large area in all segments. In case of row houses, it also has a negative impact on utility when it occupies only a small area. The presence of a busy-traffic road (both levels) has a strong negative effect in all three segments. All in all, it can be concluded that in terms of neighborhood characteristics UGS as open green area or green along street, has significant added value for a dwelling, whereas traffic and schools have repulsive effects which are particularly important for the high levels. In terms of main tendencies, we do not see clear differences between housing segments.

The accessibility-related attributes, defined as distances to CBD, to green park, to shopping and to train station, have all statistically significant effects in all three segments, at least for the high levels. As for distance to entertainment, the results are not clear-cut. This attribute is statistically significant only for the high level in the row houses segment. All in all, we see that for a wide range of urban amenities (CBD, shopping, green park, station area), accessibility has a statistically significant impact on utility of the dwelling. The segments seem to differ in terms of sensitivity to distances. For apartments, the sensitivity seems to be higher for accessibility of shopping area and train station.

Finally, the estimates related to the price attribute allow us to derive WTP-values. A 10 % higher price level appears to have a statistically significant negative effect as expected. However, a 10 % lower price level has in none of the segments, a statistically significant positive effect. Thus, we see an asymmetry in evaluation where a loss (a higher price) has a bigger impact than a gain (a lower price) of the same size. Although this is in line with the well-known tendency of loss aversion that has been shown to play a role in housing choice (Bao and Meng, 2017; Zeng et al., 2019; Ossokina and Arentze, 2022), the occurrence of complete insensitivity for a lower price is unexpected. Since a decreasing

[2] The assumption of linearity was tested by also estimating a model that allows for non-linear utility effects of amount of green. The estimation results of this latter model indicate that the utility effects are approximately linear.

Table 4
Detailed estimation results of the mixed logit models.

		Apartment		Row		Detached	
Attribute	Level	β	Sign.	β	Sign.	β	Sign.
Constant		0.31	***	0.12		0.35	***
	10 % lower	0.04		-0.24	*	0.19	
	About the same	0.00		0.00		0.00	
Dwelling price	10 % higher	-0.76	***	-0.50	***	-0.69	***
Green open area	% neighborhood area	0.04	***	0.04	***	0.03	***
	No	0.00		0.00		0.00	
	Some	1.18	***	1.62	***	1.34	***
Green along streets	A lot	2.03	***	1.90	***	1.68	***
	0 %	0.00		-0.25		0.00	
	25 %	-0.05		-0.51	**	-0.10	
School complex	50 %	-1.39	***	-1.95	***	-2.01	***
	No	0.00		0.00		0.00	
	Some	-1.23	***	-1.48	***	-1.46	***
Road traffic	A lot	-2.26	***	-2.97	***	-3.12	***
	10 min walking	0.00		0.00		0.00	
	10 min cycling	-0.11		-0.18		0.11	
Distance to CBD	20 min cycling	-0.96	***	-1.00	***	-0.38	*
	5 min walking	0.00		0.00		0.00	
	15 min walking	0.07		0.35	**	-0.11	
Distance to entertainment	15 min cycling	-0.15		0.26		-0.13	
	≤ 10 min walking	0.00		0.00		0.00	
	≤ 10 min cycling	-0.18		-0.22		-0.33	*
Distance to green park	> 10 min cycling	-0.33	*	-0.48	**	-0.36	*
	5 min walking	0.00		0.00		0.00	
	10 min walking	-0.29	*	-0.20		-0.33	
Distance to shopping	15 min cycling	-1.30	***	-0.97	***	-1.29	***
	≤ 10 min walking	0.00		0.00		0.00	
	≤ 15 min cycling	-0.75	***	-0.28		-0.19	
Distance to train station	> 15 min cycling	-0.61	***	-0.35	**	-0.68	***
Standard deviations of random parameters							
Dwelling price	10 % lower	-	-	0.77	***	0.93	***
	10 % higher	0.93	***	-	-	-	-
Green open area	50 %	-	-	1.73	***	-	-
Green along streets	Some	1.28	***	-		-	-
School complex	50 %	-	-	1.36	***	-	-
Road traffic	A lot	1.16	***	1.08	**	1.30	***
Distance to CBD	20 min cycling	1.23	***	1.09	***	-	-
	15 min walking	-	-	-	-	0.81	***
Distance to entertainment	15 min cycling	0.80	**				
Distance to green park	> 10 min cycling	-	-	0.89	***	-	-
Distance to shopping	10 min walking	-	-	-	-	0.76	*
	15 min cycling	0.78	**	-	-	-	-
Distance to train station	> 15 min cycling	-	-	-	-	0.74	*

[*] statistically significant at 10 %.
[**] statistically significant at 5 %;
[***] statistically significant at 1 %;

price trend is not common in housing markets, respondents may have associated the lower price with a lower quality of the dwelling on attributes not shown (e.g., maintenance level) reducing the positive value of a lower price.

We base the calculation of the WTP-values exclusively on the parameter value related to the 10 % price level increase. The 10 % price decrease parameter is not statistically significant and, hence, is not a reliable basis for estimating WTPs.

Table 5 shows the derived WTP-values for the levels of the attributes relative to the base level. Note that the WTP-values refer to percentage increase in price. For example, the WTP for an increase of one percent green open area in the direct neighborhood for an apartment equals 0.5 %. Looking at the WTP-values overall one may remark that the values generally are high. For example, the WTP for avoiding a high level of car traffic in the neighborhood is as large as 60 % in case of row houses. The high WTP-values may indicate that the price attribute was somewhat undervalued by respondents, which might be a bias of the stated choice experiment more generally (Arentze and Molin, 2013). As long as this bias is the same across the segments, it should not cause a problem for the present modeling purpose. The primary reason for the use of WTP-values here is to transform utility values to a common scale across the models, which is a purpose it still fulfills even if they are overestimated.

5. Housing land-use model (HLM) application

In this section, we discuss an application of the HLM, to demonstrate how the estimated stated choice model can be used for housing land-use planning. We first introduce the plan area considered and next discuss the land-use model results.

5.1. The plan area and housing construction program

For the illustration purpose, we consider housing development in Meerhoven, as a case. Meerhoven is a new city district on the North-West side of Eindhoven - the fifth Dutch city. The actual development of the area took place between 1995 and 2020. The district covers almost 300 ha and consists of 4 residential neighborhoods, one commercial area and a big green park. A shopping center is located in the center of the Meerhoven district. Fig. 3 represents a simplified land-use map of the Meerhoven area including the area designated for housing development.

Table 5
Willingness-to-pay (WTP) values as percentage increase in price.

		Apartment	Row	Detached
Attribute	Level	WTP	WTP	WTP
Constant		4.10	2.40	5.10
	10 % lower	0.50	-4.80	2.80
	About the same	0	0	0
Dwelling price	10 % higher	-10.0	-10.0	-10.00
Green open area		0.50	0.84	0.430
	No	0	0	0
	Some	15.50	32.40	19.40
Green along streets	A lot	26.70	38.00	24.30
	0	0	0	0
	25 %	-0.70	-10.2	-1.40
School complex	50 %	-18.30	-39.00	-29.10
	No	0	0	0
	Some	-16.20	-29.60	-21.20
Road traffic	A lot	-29.70	-59.40	-45.20
	10 min. walking	0	0	0
	10 min. cycling	-1.40	-3.60	1.60
Distance to CBD	20 min. cycling	-12.60	-20.00	-5.50
	5 min. walking	0	0	0
Distance to	15 min. walking	0.90	7.00	-1.60
entertainment	15 min. cycling	-2.00	5.20	-1.90
	≤ 10 min walking	0	0	0
	≤ 10 min cycling	-2.40	-4.40	-4.80
Distance to green park	> 10 min cycling	-4.30	-9.60	-5.20
	5 min. walking	0	0	0
	10 min. walking	-3.80	-4.00	-4.80
Distance to shopping	15 min. cycling	-17.10	-19.40	-18.70
	≤ 10 min walking	0	0	0
	≤ 15 min cycling	-9.90	-5.60	-2.80
Distance to train station	> 15 min cycling	-8.00	-7.00	-9.90

*** statistically significant at 1 %; ** statistically significant at 5 %; * statistically significant at 10 %.

To illustrate the application of the HLM, we assume the original state of the area before the new housing development commenced as the existing state. This is implemented by setting the current and planned residential area as developable land. Some land-uses within the planned area, including roads, the shopping center and the large urban park in the middle, are considered as given and fixed. In addition to housing, locations for public buildings which cover a total area of 4 cells are also considered free to choose. This means that public building is considered a developable land-use. The larger Eindhoven city area, which extends on the South-East side of the district, although not shown on the map, is relevant as well to determine accessibility variables related to facilities located outside Meerhoven. This includes the city center of Eindhoven, a local train station and a large urban park (outside Meerhoven). The closest train station is the Strijp-S train station located about 1.9 kilometer east of Meerhoven.

Table 6 shows the assumptions regarding the housing construction program. In total 5100 new dwellings are programmed (currently, 4500 dwellings have been developed). For the simulation, we assume that 25 % of them are apartments, 60 % row houses and 15 % (semi-)detached. This corresponds to a typical distribution across housing types in city expansion areas such as Meerhoven. Two scenarios are considered – a public welfare-oriented scenario where WTP-values are specified in relative terms (as in Table 5) and a market-value-oriented scenario where these WTP-values are weighted with average housing price levels for apartments, row, and detached houses, respectively. Table 6 shows the housing price weights assumed which are representative for the housing markets and assumed dwelling densities for the housing types.

5.2. HLM model results

To implement the estimated model using the WTP-values (Table 5) in the HLM, the travel time levels of the distance attributes need to be translated to geographic distances. Considering the Dutch context, we assume 4.5 km/h and 15 km/h for walking and cycling speed, respectively, to translate the travel times to distances. The land-use attributes are implemented as follows. The attribute open green area is expressed

Table 6
Housing program, housing densities, land demands, and housing price weight assumed for the application.

Type of dwellings	Apartments	Row houses	Detached
Share in %	25	60	15
Number of dwellings	1275	3060	765
Density in dwelling/ ha	100	46	20
ha (number of cells)[a]	13	67	38
Housing price weight (price ratio)	1	1.125	2.063

[a] The figures are obtained by dividing the number of dwellings by the density.

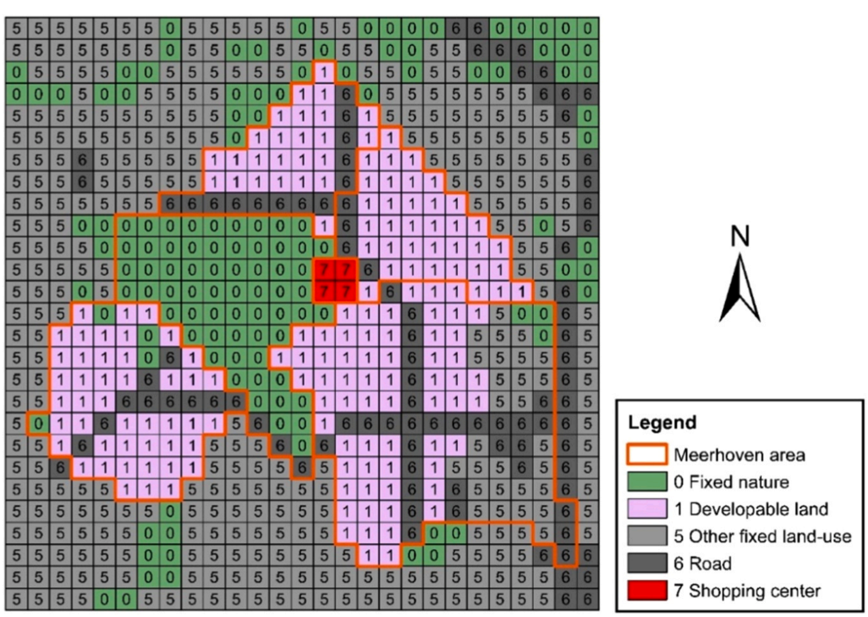

Fig. 3. Land use map of Meerhoven.

as a percentage of land coverage and hence can readily be implemented as the percentage of the neighborhood area of a housing cell used for UGS. The attribute school complex is implemented in the same way using interpolation for coverage levels in-between 0, 25 % and 50 %. For road traffic the number of road cells in the neighborhood of a housing cell is important, assuming a high level when 50 %, medium level when 25 % and zero level when 0 % of the adjacent cells are road cells. Finally, we assume that green along streets is not a pre-designed feature of road cells, but rather can be realized by allocating UGS adjacent to roads as a possible outcome of spatial allocation decisions of the HLM. Therefore, green alongside street is not included as a specific attribute.

Fig. 4 shows the results for the two scenarios. In the price-weight scenario (scenario 1), all apartment locations have green cells in the direct neighborhood and many of them are close to the central big green park. It is noted that due to its high density (F in Eq. 3), apartments obtain priority above row and detached housing in the allocation process aimed at maximizing the overall WTP. Detached houses are not close to green cells, due to the relatively low WTP value for this quality which may be because detached houses have their own garden. Instead, most detached houses are allocated at the northeast part of Meerhoven where they benefit from relatively good accessibility of the shopping area, the Eindhoven city center and the local train station. Public buildings are located alongside roads. Green cells are located close to main roads where they create a buffer between housing and car traffic. In Scenario 2 (without price weight), similarly, the apartments are allocated near green cells, and detached houses do not have green cells in their neighborhood. Public buildings are all located alongside roads. Green cells are mostly located along roads to create a buffer between the streets and housing.

Comparing the solutions between the two scenarios, the tendencies are largely the same. There is, however, an important difference concerning the housing type allocated to the northeast area of Meerhoven. In scenario 2 the utility of every housing type is given the same weight instead of a weight based on purchase power. Here most detached houses are pushed out of the northeast of the Meerhoven region by row houses which also show relatively high WTP for the accessibility benefits and are built in higher density and hence have higher weight in allocation decisions. In this scenario, we also see a higher degree of mixed housing types as a consequence. According to the model, this solution will reduce the value of development for housing developers but increase the utility of residents.

6. Conclusions

In this paper, we have developed and illustrated an approach to combine a stated choice experiment and a housing land-use model. The land-use model optimizes the spatial allocation of UGS and housing land-uses simultaneously. We showed how a stated choice experiment can be designed to estimate utility parameters of the land-use model including a wide range of accessibility and neighborhood attributes. A national sample of homeowners served as respondents.

The results reveal that the way trade-offs are made between a green neighborhood and accessibility to urban amenities tends to differ between housing types (apartments, row, detached). In an application, locating UGS alongside main roads to create a green buffer for housing appears to be the most beneficial way of allocating UGS considering housing preferences of homeowners. Given the estimated WTP-values, apartments are developed close to green area, and row and detached houses are at locations with good accessibility to particular urban facilities. Thus, row and detached housing compete for good accessibility locations and the solution depends on whether a market value or a resident's utility measure is maximized. By making the planning implications explicit, the proposed model allows urban planners and developers to optimize the planning of the area and find a balance between real estate development value and residents' utility.

The approach developed in this study shows how the stated choice experiment and land-use modeling can be combined to support spatial housing planning. To further develop this approach, cross-validation with revealed preference approaches remains a problem for future research. Although the stated preference method solves some of the problems of revealed approaches, it may introduce a bias in that individuals' stated preferences may not be fully consistent with their actual housing location choice behavior. Combining the specific strengths of stated and revealed approaches by combining stated choice data with revealed data (hedonic price analysis), therefore, looks promising. In the discrete choice modeling literature, such combined approaches have been developed and tested, where stated data is used for model identification and revealed data to correct for the scale of the utility parameters. Investigating this approach may increase the accuracy of parameter estimates for housing land-use models. Despite the limitations, the combined stated preference experiment and land-use modeling approach proposed in this study has clear advantages and offers useful insights for urban developers and planners for making

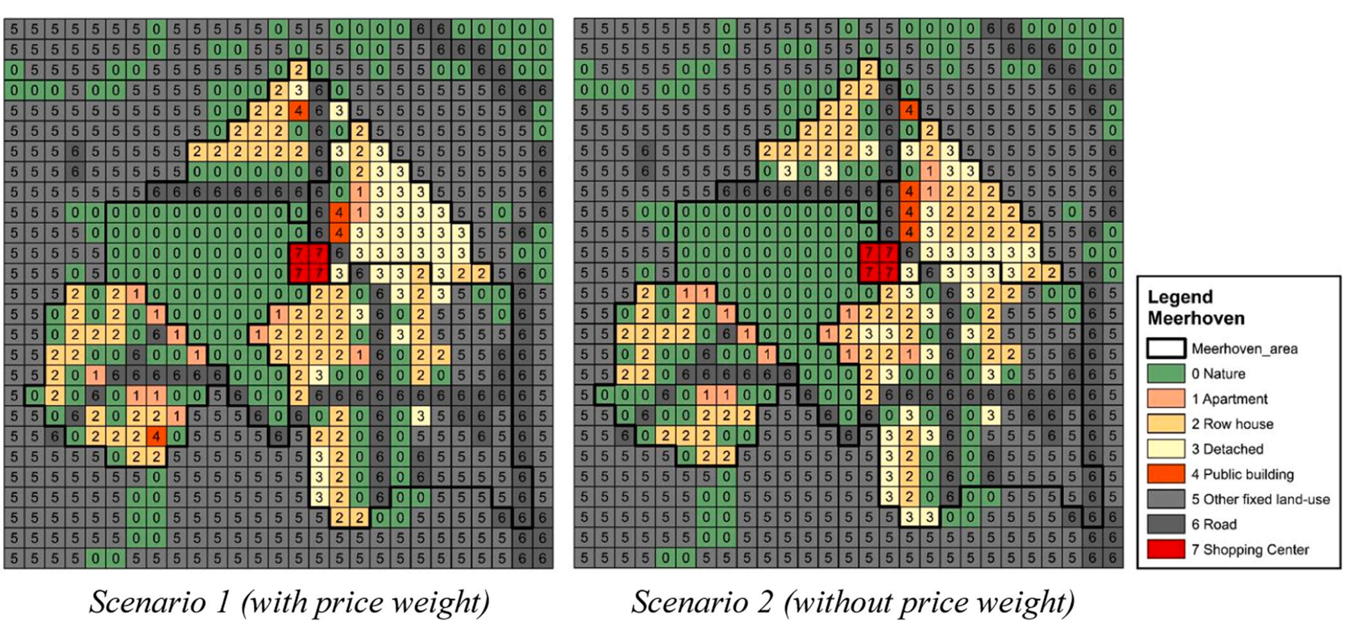

Fig. 4. HLM simulation scenarios.

housing location decisions.

CRediT authorship contribution statement

Jianfei Li: Writing – original draft, Visualization, Formal analysis. **Ioulia Ossokina:** Writing – review & editing, Supervision. **Theo Arentze:** Writing – review & editing, Supervision.

Ethical approval

The data was collected based on the regulation of the Ethical Review Board at the TU/e.

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Informed consent

N/A: The respondents signed the consent form. The data used was obtained from questionnarie which received the ethnical approval from Ethical Review Board at TU/e.

Declaration of Competing Interest

There are no conflicts of interest

Data Availability

The authors do not have permission to share data.

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