Urban Forestry & Urban Greening 95 (2024) 128293

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Understanding citizens' willingness to contribute to urban greening programs

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ARTICLE INFO

Keywords:
Urban greening
WTP
Choice Experiment
Environmental Inequality
Urban policy
MXL
Climate Change Adaptation

ABSTRACT

Urban green is an essential component of livable and sustainable cities, providing benefits for the environment, human health, and well-being. In densely built city areas, planting street trees and installing green roofs and facades can lead to more equally distributed green infrastructure, for which it gained importance in urban planning. However, to achieve the desired effects, cities need to implement small-scale measures on a large scale, which requires broader urban restructuring and significant financial and political resources. Economic valuation can support this process by providing city governments with knowledge about citizens' support and preferences for greening policies. We use a choice experiment in the Austrian capital, Vienna, as part of a representative survey of 1327 respondents. Using a Mixed Logit Model with correlated random parameters, the results show a clear preference for a greener city, while respondents express a higher marginal willingness to pay (WTP) for measures on streets (5.58 Euro/year) than on buildings (3.60 Euro/year) for change the density of green measures from rare to frequently. Introducing interactions with socioeconomic variables, selected attitudes, and neighborhood characteristics based on geo-referenced addresses, we find a positive correlation between a higher WTP and the characteristics of younger and more affluent residents, as well as citizens who suffer significantly from urban heat, use parks more regularly, and live in neighborhoods with relatively little urban greenery. Overall, the analysis proves valuable for estimating public support and facilitating comparisons between different greening options, contributing to a more informed and nuanced discussion in urban planning and policy.

1. Introduction

Urban green, such as parks, gardens, and trees, have become increasingly recognized as essential components of livable and sustainable cities. They provide various benefits to the environment, human health, and well-being, including improved air quality (Jayasooriya et al., 2017), the reduction of summer temperatures (Cruz et al., 2021; Heidt and Neef, 2008) and increased biodiversity (Aronson et al., 2017). Green spaces not only provide areas for physical activity, which enhances their potential positive health effects (Wang et al., 2019), they were also found to reduce anxiety and stress (Beyer et al., 2014; Branas et al., 2011). Moreover, natural elements in cities are visually appealing, making neighborhoods more attractive to residents and visitors alike (Bertram and Rehdanz, 2015). Considering these positive effects of urban green, the equal distribution of and access to it are crucial issues for contemporary city planning (Haaland and Van Den Bosch, 2015) and are often referred to in the environmental justice debate (Wolch et al., 2014). However, densely populated areas in many cities lack urban green elements (Han et al., 2023; Sun et al., 2022), which has been found to often disproportionately affect low-income neighborhoods (Kaur et al., 2022; Liu et al., 2020; Sikorska et al., 2020).

Providing the benefits of green to all citizens challenges local governments, especially as available land plots in urban areas are scarce and required for housing and built infrastructure in light of continuing urbanization and urban densification. In this respect, creating new, larger green areas, such as parks, is hardly feasible in the existing urban fabric. An alternative to such urban interventions, which we define due to their larger spatial requirements as "large-scale measures", are small-scale measures. Small-scale measures, such as planting street trees and greening house facades, have the potential to be implemented city-wide and have gained popularity in urban planning (Breger et al., 2019; Galenieks, 2017; Liberalesso et al., 2020). Yet, to achieve benefits to an

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https://doi.org/10.1016/j.ufug.2024.128293
Received 17 May 2023; Received in revised form 14 February 2024; Accepted 15 March 2024
Available online 24 March 2024

extent that increases citizens' well-being, these measures must be implemented extensively, requiring a major restructuring of urban spaces and significant investments as well as putting financial pressure on city governments. Given the restricted budgets of local authorities (Kabisch et al., 2016), alternative sources to finance urban greening are discussed, including environmental taxes and fees (Zimmerman et al., 2019).

Economic valuation allows estimating the value that citizens place on changes in urban greenery and urban green infrastructure, giving city governments insight into how supportive citizens are of new policies. Different methods have been used in this regard, from revealed- to stated preference. For instance, while larger parks and (peri-)urban green spaces are usually valued using the Travel Cost Method, mainly focusing on their recreational benefits (e.g., Cetin et al., 2021; Hanauer and Reid, 2017), the Hedonic Pricing Method enables estimation of the marginal willingness to pay for green amenities by analyzing the influence of their proximity on property prices, reflecting preferences (e.g., Czembrowski and Kronenberg, 2016; Ramírez-Juidías et al., 2022; Saphores and Li, 2012). The aforementioned revealed preference methods are suitable valuation approaches as long as the required data is available, for example, information on transaction prices or travel choices. In the absence of specific revealed preference data, stated preference methods can be used with great advantage of hypothetical settings that allow to elicit preferences and willingness to pay in hypothetical scenarios. These methods are widely used in non-market valuation and are often applied in environmental economics, transport and health valuation. They were also used to value larger green spaces (e.g., Latinopoulos et al., 2016) as well as small-scale greening interventions in cities. Morawetz and Koemle (2017) employed a Contingent Valuation Method to study the willingness to pay (WTP) for programs increasing the number of street trees and fountains in Vienna. In recent years, choice experiments were, for instance, applied in the valuation of street trees, e.g., in Hong Kong (Ng et al., 2015) and Łódź (Giergiczny and Kronenberg, 2014), green roofs in Portland (Netusil et al., 2022) as well as to value different greening measures for case study streets in Berlin (Fruth et al., 2019) and Taipei (Botes and Zanni, 2021). Except for Badura et al.'s (2021) analysis of greening measures in Prague, the existing literature, therefore, focused either on single greening measures or highly localized study areas, often also drawing on a small sample size of respondents. Building on this, we apply a Discrete Choice Model to answer the first research question: **(1) To what extent do Vienna's citizens favor the implementation of urban greening programs consisting of city-wide small-scale greening measures, and what preference structures can be identified?** We focus on urban greening programs, which we define as the sum of local greening measures to be implemented in a systematic way to achieve more equal distribution of green infrastructure across the city. In this case, the main advantage of using a DCE instead of a CVM is the ability to examine the tradeoffs between attributes, which is useful when analyzing hypothetical (greening) programs that consist of multiple measures to be compared. Our study area, Vienna, despite its reputation as a green city, has a heterogeneous distribution of green spaces, making it an interesting case for discussing issues of accessibility and equity of urban green spaces across neighborhoods. To obtain city-wide relevant estimates, we use a large and representative sample which is also geographically balanced across the districts.

Utilizing a mixed logit model (MXL) in conjunction with individual characteristics enables us to address a second research question, namely **(2) How do preferences for green elements differ across different social groups?** The objective is to provide information on socioeconomic and socio-spatial heterogeneities, which might also support the formulation of policies that specifically address groups with varying levels of support for urban greening. Characteristics for which significant effects on the WTP for urban green elements were found include socioeconomic characteristics, such as age or income (e.g., Morawetz and Koemle, 2017; Shao et al., 2020; Sirina et al., 2017) as well as environmental attitudes (Muhammad et al., 2021) and experiences with problems connected with lacking urban green, such as urban heat (Badura et al., 2021), and selected greening measures (Netusil et al., 2022). We not only test the influence of similar variables but also include variables connected to the place of residence of the respondents. Accordingly, information on the respondents' home addresses allows us to include the level of green in proximity to the places of residence as a potential influence for the WTP.

Thus, this paper contributes to existing literature in three ways. First, the analysis draws on an extensive and diverse sample of Viennese citizens, providing a comprehensive understanding of their attitudes and preferences towards urban greening policies. Moreover, the inclusion of geo-referenced addresses allows for the consideration of the supply of urban green at the respondents' place of residence, further enhancing the accuracy and relevance of our findings. Second, we focus on small-scale measures, which do not require as much space and financial resources as larger-scale measures, such as parks, and are, therefore, often a more feasible and accessible solution for increasing a city's green space (Navarrete-Hernandez and Laffan, 2023). Lastly, by utilizing MXL, this research employs state-of-the-art choice modeling techniques, providing a rigorous and precise approach to valuing the benefits of urban greening policies.

The paper is structured as follows: Section 2 presents Vienna, the study area, the choice experiment and discusses the choice of attributes, the experiment design, the sample population and the modeling approach. The results of the choice experiment are shown in Section 3 and discussed in Section 4. Finally, we conclude with some limitations and further potential research avenues in Section 5.

2. Data and methodology

A Discrete Choice Experiment (DCE) was conducted to investigate the preferences of Viennese citizens regarding urban greening programs. The theoretical basis of a DCE is Lancaster's characteristics of value theory (1966), stating that a good can be described by its characteristics and the levels these may take. In multiple-choice situations, respondents choose between alternatives, which are represented by varying attribute levels. The analysis of choices allows determining the respondent's sensitivity towards marginal changes of the attributes and, if a cost attribute is included, to separately estimate the economic value they place on individual attributes, as shown by their willingness to pay (Hanley et al., 2001). It is worth mentioning that the literature agrees that after fulfilling certain conditions (i.e., the incentive compatibility or consequentiality), the results from stated preference studies are in line with those obtained from revealed preference studies (Carson et al., 2014; Carson and Groves, 2011; Collins and Vossler, 2009; Vossler and Evans, 2009). In our study, we followed the guidelines for environmental valuation studies from Bateman et al. (2002) and Mariel et al. (2021).

2.1. Study area

Austria's capital, Vienna, was selected as a study site for the choice experiment. While the city is internationally recognized as a green city, there are still areas, especially in the inner-city districts, where an inadequate supply of urban green spaces can be found (Brenner et al. 2022). While there is general political support for increasing the city's supply of green amenities, the existing inequalities make it an interesting testbed for the choice experiment.

Historically, Vienna can be considered a European pioneer in urban green planning (Brenner et al. 2022), with milestones such as the 1905 decision to secure the green belt of forest and agricultural land around the city as recreational areas, the establishment of green zones on half of the building area of social housing constructions after the First World War, and the definition of overarching green spaces and connections in the 1984 Development Plan (MA18, 2015). Today, 50 percent of the

Table 1
Choice experiment attributes and related levels.

Attribute	Explanation	Levels
Attribute 1: Measures on streets ('Streets')	Street trees, planters and green strips	Rarely, scattered, frequently and everywhere
Attribute 2: Measures on building ('Build')	Green facades and roofs	Rarely, scattered, frequently and everywhere
Attribute 3: Street furniture ('Furniture')	E.g., benches and sprinklers	Rarely, scattered, frequently and everywhere
Cost attribute: Monthly fee ('Cost')	Individual contribution to earmarked greening fund	1€, 2€, 3€, 4€, 5€, 6€

city's administrative area is green space; however, this includes large forests and agricultural areas on the outskirts of town. The historical focus on large recreational areas has contributed to an uneven distribution of green spaces throughout the city (Haslauer et al. 2014). A comparison with three similar-sized European cities (Rotterdam, Copenhagen, and Munich), for instance, showed that Vienna's neighborhood streets are less planted and that more space is dedicated to parking spaces due to the practice of angle or perpendicular parking (Furchtlehner and Lička, 2019).

The city government's current urban greening initiatives have a stronger focus on reaching underserved areas, which is in line with its principle of green space equity, which states that "all citizens have the same right to high-quality provision of green and open space." (MA18, 2015: 15) Small-scale greening measures, which are at the heart of this approach, have also become Vienna's main strategy for adapting to increasingly high summer temperatures. Especially in densely populated areas where urban heat islands are most prevalent, there are many streets that lack greenery. Therefore, the greening of streetscapes by expanding the urban tree stock and other greenery is considered crucial (MA22, 2018). However, while there is political will to promote the greening of Vienna, the process is challenging. These challenges encompass, for instance, issues such as technical feasibility and legal considerations, including property rights (Friesenecker et al., 2023; Sarabi et al., 2020). For example, while district governments have the authority to redesign streetscapes, greening of buildings and courtyards depends on who owns the building.[1] Further, there are competing interests in the use of public space (e.g., trees vs. parking spaces) and changing political (local) actors who might be cautious about avoiding public resistance to proposed urban redesign programs. Recognizing the importance of public opinion in navigating these challenges and understanding the support for city-wide greening initiatives can be instrumental in shaping and refining urban greening policies.

2.2. Choice and experimental design

In the choice experiment, the respondents had to decide between two unlabeled greening scenarios and the status quo (SQ).[2] The scenarios were presented as Vienna-wide urban greening programs to be implemented in the next five years, which consist of the implementation of small-scale greening measures to improve citizens' quality of life, especially by providing heat relief in the summer. Each of the programs was described along the lines of three attributes, representing different types of clearly distinguishable measures, which were chosen according to four criteria: All selected measures 1) require relatively little space, which makes them city-wide implementable, 2) depend on financial resources, 3) provide benefits that are commonly understood, and 4) are within the city government's scope of influence, directly or indirectly through funding. Table 1 summarizes the attributes and their levels.

In the scenarios, two types of small-scale greening measures were included, distinguished according to whether they are implemented in streets and public spaces or on buildings. The first category consists of street trees, planters and green strips added to the existing streetscape, while the second category focuses on green facades and roofs. Both types of measures not only provide regulating ecosystem services, e.g., by ameliorating the microclimate and air quality, but they also have visual and aesthetic benefits (Roy et al., 2012), were found to improve mental health (Branas et al., 2011) and support physical activity (Wang et al., 2019). Half of the sample was presented with pictograms highlighting the measures' effect of urban heat.[3] Additionally, each alternative contains the attribute street furniture intended mainly as a control variable. Since greening measures are often accompanied by a general redesign of urban public areas, the street furniture attribute aims to separate general preferences for streets with a higher quality of stay from the preferences for actual greening measures. Thus, the effect the WTP found for greener surroundings should not be influenced by the respondents' wishes for amenities, such as benches or fountains. Prior to the experiment, the respondents received comprehensive information on how the measures would be implemented, their effects on the urban climate, and photographs with examples.[4]

Each attribute consists of four levels, representing how densely the measures are implemented: Rarely, scattered, frequently and everywhere. While the first attribute level represents the status quo,[5] the other three levels relate to improving the cities' (green) infrastructure. A depiction of the density of the proposed measure complemented each of the pictograms used in the choice experiment. For instance, it was shown how the share of buildings, on which green facades and roofs are installed, changes from level to level. These changes were also quantified and explained verbally: the level "scattered" corresponds to greening every third suitable house, "frequently" refers to every second and "everywhere" introduces green roofs and facades on every suitable house.[6]

The last attribute is the price of each scenario. A monthly contribution to an earmarked fund was chosen as a payment vehicle in the choice experiment. The cost attribute ranged from 1 to 6 Euros per month and was also presented as an annual sum (12–72 Euros per year).[7] Respondents were informed that the payment would be mandatorily collected from each Viennese citizen and, therefore, would be similar to a universal and binding environmental tax or fee. Moreover, it was highlighted that the implementation of the proposed greening programs would depend on the financial contribution of citizens, thus addressing the issue of policy consistency (Mariel et al., 2021). However, it was

[1] In order to encourage the greening of privately owned real estate, the city has implemented financing programs (Wien.gv.at, 2024).

[2] An example of a translated choice card can be found in the Appendix (Figure 1).

[3] The differences between the two versions of representing the greening measures on the choice cards are accounted for in the model with interactions. However, a comprehensive analysis of potential effects on preferences and WTP is part of ongoing research.

[4] A translation of the information provided to the respondents prior to the experiment is provided in the Online Appendix.

[5] Although there are many neighborhoods in Vienna that are well supplied with greenery, especially street trees, the rare level was used as the baseline. This was done because the choice experiment tests the preference for a citywide program, and to remind respondents of the areas in the city that still lack green amenities.

[6] The quantitative and qualitative definition of the levels of each attribute as they were presented to the respondents can be found in the Appendix in Table 7.

[7] The base reference for setting the cost attribute was Vienna's yearly budget for greening activities (including maintenance) which equals 13€ per inhabitant (City of Vienna 2023). We then conduced a literature review of similar choice experiments, discussed the attribute during the qualitative pre-tests, and finally decided that a cost attribute with equal steps is appropriate also as it presents to the respondents as a straightforward and easily comprehensible scale.

Table 2
Characteristics of the respondents (n = 1.327).

Socio-economic variables	Variable	Sample mean	Vienna
Gender			
	Male	49.5%	48.9%[a]
	Female	50.5%	51.1%[a]
Age			
	<30 years	23.5%	34.0%[b]
	>30 – 55 years	51.6%	38.2%[b]
	>55 years	24.9%	27.8%[b]
Highest Education			
	Elementary School, Apprenticeship	47.8%	52.3%[c]
	Highschool	25.9%	19.7%[c]
	Tertiary Education	26.4%	27.9%[c]
Monthly net household income			
	<2.000€	35.8%	
	2.000–4.000€	42.9%	
	>4.000€	21.2%	
Additional survey-related variables	Variable	Sample mean	
Garden			
	Household has garden	17.6%	
Heat Sensitivity Index[1]			
	Low (Index <2)-	9.1%	
	Medium (Index 2–4)	54.5%	
	High (Index >4)	36.4%	
Usage of green spaces			
	More than once per week	51.2%	
	Less often	48.8%	

Sources: a) City of Vienna (2023a) b) Statistics Austria (2021) c) Statistics Austria (2019)
[1]The index is based on four self-reported items. Each question was answered on a five-level Likert scale (1 totally disagree to 5 totally agree). The individual heat sensitivity index is an unweighted mean of the responses.

- When outside temperatures exceed 30°C, I feel uncomfortable in my everyday life.
- Heat negatively affects my health.
- The increase of very hot days in Vienna, has burdened me in the last few years.
- I sleep worse if it stays very warm at night (>20°C).

refrained from further explaining how this payment mechanism would be carried out, as it has been found that detailed descriptions of the mechanism can increase the number of protest responses since the payment could be perceived as avoidable (Bateman et al., 2002).

Using the software Ngene, an experimental design was found for the choice cards representing greening programs consisting of different combinations of attribute levels with high D-efficiency (D-error of 0.0317). In total, 24 different choice cards were created and divided into four blocks. Each respondent was confronted with one of the blocks, consisting of six choice situations.

2.3. Data collection and sample population

The questionnaire development process involved collaboration among a diverse project team and was pre-tested qualitatively and quantitatively to ensure a comprehensive assessment of the survey content.[8] The final questionnaire was distributed in May and September 2022[9] through an online panel provider, with respondents being individuals who regularly participate in surveys and are compensated for their contributions.[10] This methodology facilitated the acquisition of a substantial sample size and allowed for a comprehensive survey, with flexible questioning, the inclusion of visual elements, and the shuffling of choice cards and response options to mitigate potential ordering effects (Day et al., 2012). The choice experiment was part of a larger survey that included questions regarding the respondents' socioeconomic background, their usage of green areas, attitudes towards (urban) heat and information on living conditions. Moreover, information on the respondent's current addresses was collected, which allowed joining the responses from the survey with local information, such as the number of parks in proximity.

A total of 1327 Viennese citizens completed the questionnaire and

[8] Test links to the online version of the survey were sent out to experts in the fields of social and political sciences and spatial planning. This step resulted in feedback from 26 experts, mostly regarding issues such as wording, missing answer options, or inconsistencies in question logic. After the questionnaire was refined accordingly, the online panel provider launched a pre-launch of 100 responses prior to both rounds of questioning, which were again carefully analyzed to identify potential problems. However, no significant changes were made based on these results.

[9] The questioning was split into two rounds to investigate the effects of experiencing summer temperatures on WTP. However, as the differences between the two rounds are marginal, the results are combined in the analysis.

[10] While these "professional" respondents are likely to be more familiar with responding to surveys than, for example, a random street sample, the online panel provider has a process in place to minimize the threat of fraudulent respondents. This includes tracking response time and weeding out respondents who are too fast or too slow, comparing results to the information provided at the time of panel registration, and identifying unrealistic and obviously false answers in every survey the panelist participates in. Respondents with suspicious response patterns will be excluded from the entire panel, not just individual surveys. In addition, the company invites respondents in a gradual process and prevents them from participating in surveys with similar topics and generally too often to reduce learning and panel effects Marketagent.com n.d.).

Table 3
Overview of interacting variables.

Variable	Description
Age	Classification in three age groups: 18–30, 30–55 and 55–69 years
Income	Classification according to income quartiles, comparison bottom 25% and top 25% with the middle 50%
Kids	Dummy variable indicating if children (younger than 14 years) live in the household
Heat-sensitivity	Dummy variable based on a heat-sensitivity index (see Table 2), indicating if respondents have a high heat sensitivity (4 and above on a scale from 1 to 5)
Heat Info	Dummy variable indicating if the respondents received choice cards with a graphical indication of the heat-reducing effect of the measures
Regular users of UGS	Dummy variable indicating if respondents use Vienna's green areas more than once a week
Owner of gardens	Dummy variable indicating if respondents live in houses with private gardens
Green spaces at place of residence	Dummy variable based on a 500-meter buffer around place of residence. Addresses surrounded by more green spaces than the median of the sample
Trees at place of residence	Dummy variable based on 500-meter buffer around place of residence. Addresses surrounded by more trees than the median of the sample

the choice experiment discussed in this paper.[11] The sample was chosen to be representative of Vienna's population across gender, income, age and distribution over the 23 districts. Table 2 summarizes the sample structure. The lack of participation of very young and older people is one of the downsides of online surveys. Our age range was restricted to 18–69 years, leading to an overrepresentation of people aged 30–55 years.

2.4. Modeling approach

Under the premise of utility maximization, a respondent will choose the alternative of a choice set with which they associate the highest utility. Following the random utility framework (McFadden, 1974), each respondent's (i) indirect utility function (U) consists of two elements: a deterministic part (V), typically a linear function of the observed attributes ($\boldsymbol{X}_{itj}$) of the different alternatives in the choice set multiplied by the corresponding vector of parameters ($\boldsymbol{\beta}_i$), and a stochastic part (e_{itj}), the random error term, representing all unobservable influences on individual decisions. The utility of choosing alternative j for an individual i in choice situation t can be thus expressed as:

$$U_{itj} = \boldsymbol{V}_{itj} + e_{itj}$$

This study applies a mixed logit model (MXL), also known as a random parameter logit model, which is an alteration of a simple multinomial logit model (MNL). The MXL model allows for preference heterogeneity by assuming that the parameters are no longer fixed (as in the MNL model) but can be derived from a statistical distribution (mostly by normal, lognormal and triangular distributions). Such action resolves a problem related to MNL application, namely the fulfillment of the independence of irrelevant alternatives (IIA) assumption and the restrictive independent and identically distributed (IID) parameter assumptions for the extreme value type 1 (EV 1) distribution of the random term. Thus, the conditional probability of choosing a particular alternative can be described as:

$$P_{ijt}(\beta_i) = \frac{\exp(\boldsymbol{X}_{itj}\boldsymbol{\beta}_i)}{\sum_{k=1}^{K}\exp(\boldsymbol{X}_{itk}\boldsymbol{\beta}_i)}$$

On the contrary, the unconditional choice probability, assuming that the vector of parameters $\boldsymbol{\beta}_i$ follows a distribution $f(\beta_i|\Omega)$, can be expressed as:

$$P_{ijt}(\beta_i|\Omega) = \int_{\beta_i}\left[\frac{\exp(\boldsymbol{X}_{itj}\boldsymbol{\beta}_i)}{\sum_{k=1}^{K}\exp(\boldsymbol{X}_{itk}\boldsymbol{\beta}_i)} \quad f(\beta_i|\Omega)\right]d\beta_n$$

Subsequently, this formula can be implemented into a log-likelihood function:

$$LL(\beta_i|\Omega) = \sum_{i=1}^{N}\ln(P_{ijt}(\beta_i|\Omega))$$

However, for parameters described by a given statistical distribution, simple log-likelihood maximization is not sufficient since it is no longer possible to compute such an integral. Therefore, simulated log-likelihood maximization can be used to find the best set of parameters to maximize the log-likelihood function. This study uses 2000 Sobol draws (Sobol', 1967) with Owen (Owen, 1995) and Faure-Tezuka (Faure and Tezuka, 2002) scrambling (Czajkowski and Budziński, 2019). Table 3

2.4.1. Application

First, a MXL model with correlated random parameters (Mariel and Meyerhoff, 2018) without interactions is calculated (a model that only included the attributes). Thereby, a custom-written software specifically designed to work with the DCE package in Matlab was used (Czajkowski, 2024).[12] Since it must be doubted that all respondents perceive the distances between the levels of the categorical attributes (measures on streets and buildings, street furniture) as even, the attributes were treated as factors with three-factor levels of change (scattered, frequently and everywhere). The coefficients were estimated relative to the status quo level (rare). While the preferences regarding the attributes are assumed to be normally distributed, the cost attributed is treated as log-normally distributed. In addition to the attributes explained in Table 1, an alternative specific constant (ASC) is included in the estimation. The ASC is a dummy variable, taking the value 1 if the chosen option is a change of the status quo (i.e., ASC represents preference toward not choosing a status quo alternative). This approach captures variation in the respondents' preferences for choosing an alternative that cannot be explained by the attributes.

While the random components of the attributes in the first MXL model already integrate varying preferences across respondents, no information on structural differences in the sample is given. Therefore, a second model was estimated in which respondent-specific variables were interacted with the model attributes to gain insight into respondent

[11] The online panel provider invited 18,901 respondents to the first wave in May and 27,674 to the second wave in September 2022. In total 3038 respondents started the survey of which 272 dropped out voluntarily and another 576 were stopped from completing the questionnaire due to quota management or as they encountered screen-outs, resulting in 2191 completed questionnaires. As the choice experiment was designed as a three-split experiment, of which only two parts are analyzed in the framework of this paper, the relevant number of participants is 1327. The market research company's approach to invite their complete panel, though enabling a fast completion might also introduce some unobservable bias, especially as no data is available on who did not participate in the survey and their reasoning. However, the company stated that the respondents did not receive information on the survey prior to their participation except the title "Heat in the city" and the length of the survey. Therefore, the effect of respondents not participating due to the topic of urban greening should be minimized.

[12] The data and codes can be found in the Online Appendix.

Table 4
Mixed logit model estimates and willingness to pay (WTP) values (in Euros per individual and year).

	Dist.	MXL in preference space		Annual WTP	
		μ parameter (std. error)	σ parameter (std. error)	Mean (std. error)	CI 2.5% | CI 97.5%
ASC	norm	3.35*** (0.36)	3.57*** (0.36)	7.94** (3.17)	2.82 | 15.17
Street 1	norm	1.38*** (0.19)	1.26*** (0.32)	3.33** (1.49)	1.06 | 6.85
Street 2	norm	2.32*** (0.22)	2.15*** (0.22)	5.58** (2.44)	1.81 | 11.26
Street 3	norm	2.51*** (0.19)	2.19*** (0.21)	6.04** (2.61)	1.99 | 12.09
Build 1	norm	0.80*** (0.15)	1.55*** (0.36)	1.92** (0.90)	0.59 | 4.06
Build 2	norm	1.50*** (0.17)	2.20*** (0.42)	3.60** (1.61)	1.15 | 7.39
Build 3	norm	1.60*** (0.14)	2.12*** (0.35)	3.84** (1.65)	1.28 | 7.66
Furniture 1	norm	-0.14 (0.14)	1.29*** (0.23)	-0.32 (0.38)	-1.18 | 0.38
Furniture 2	norm	0.25* (0.14)	1.52*** (0.24)	0.62 (0.46)	-0.05 | 1.73
Furniture 3	norm	0.27*** (0.09)	1.88*** (0.28)	0.65* (0.37)	0.13 | 1.55
Cost	log-norm	-5.69*** (0.28)	3.13*** (0.22)		
Model diagnostics					
LL at convergence		-5576.12			
LL at constant(s) only		-7903.24			
McFadden‘s pseudo-R^2		0.29			
Ben-Akiva-Lerman‘s pseudo-R^2		0.52			
AIC/n		1.42			
BIC/n		1.49			
n (observations)		7962			
r (respondents)		1327			
k (parameters)		77			

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

heterogeneity. The following tables provide an overview of the additional variables that were included in the model:

In the second MXL model, the number of coefficients was reduced by pooling attribute levels, i.e., changes from *rare* to *frequently* and *rare* to *everywhere* were combined and compared with no or only minor changes (*rare* to *scattered or more*).

We also simulated willingness to pay measures using the method by Krinsky and Robb (1991) using 100,000 iterations and 100,000 draws (in each iteration) from a multivariate normal distribution (with a vector of estimated parameters from the MXL model without interactions as mean and corresponding asymptotic variance-covariance matrix, an inverse Hessian, as the variance). This allowed us to receive information on the standard errors and confidence intervals of obtained welfare measures (Bliemer and Rose, 2013; Hole, 2007).

3. Results

3.1. MXL base model

Table 4 shows the results of the MXL model in preference space (the means and standard deviations of the parameters are presented on the left side of the table) and how they translate into WTP values (right side of the table). Most mean coefficients and the standard deviations of the parameters were found to be statistically significant. The highest preference coefficient and annual marginal WTP (7.94€) are found for the ASC, indicating that respondents generally prefer a change over the status quo, a preference that cannot be entirely explained by the attributes. The cost attribute's coefficient is significant and shows the expected sign, as respondents prefer less costly alternatives.

The attributes related to greening of streets and on buildings have significant positive coefficients for all levels. Respondents have higher marginal WTP for measures on streets than for green roofs and green facades, while the coefficients for street furniture are generally much lower. An increase in street trees and planters from *rare* to *scattered* is valued at 3.33€/year, from *rare* to *frequently* at 5.58€/year and from *rare* to *everywhere* at 6.04€/year. Measures on buildings have annual marginal WTP values of 1.92€, 3.60€ and 3.84€. Regarding the installation of benches and fountains, the coefficient for the *scattered* level is not significantly different from 0, while the other two levels are positive and significant (0.62€/year from *rare* to *frequently* and 0.65€/year from *rare* to *everywhere*). Further, as 'furniture' was intended as a control variable, it ensures that the effects of greening and those of other benefits of urban redesign can be separated. The low WTP for street furniture indicates that respondents value greening and its benefits, such as reducing summer temperatures, significantly higher than elements such as benches or fountains.

The coefficients of all attributes increase with the extent of implemented measures (higher level). However, while the distance between the status quo and the first level (*scattered*) and the first and second level (*frequently*) is pronounced for both attributes, the distance between the *frequently* and *everywhere* level is quite small. This suggests a saturation effect or a scale sensitivity problem. Based on this finding, we conducted a Wald test to analyze whether there is a statistical difference between the coefficients for the different levels of the attributes. The results (see

Table ***8*** in the Appendix) show that while the null hypothesis (coefficients are equal) can be rejected for all tests examining the difference between the first and second levels (*scattered* vs. *frequently*) and the first and third levels (*scattered* vs. *everywhere*), this is not the case for the comparison between the second and third levels. Accordingly, we cannot reject the null hypothesis for the coefficients describing the densest levels of attributes (level 2-*frequently* and level 3-*everywhere*) for measures on streets (t=1.24, p-value=0.27), street furniture (t=0.01; p-value=0.92), and measures on buildings (t=0.66, p-value=0.42). This evidence suggests that respondents could not distinguish the difference between *frequently* and *everywhere* distributed measures.

Another strand of analysis is to assess the interactions between attributes, for which we estimate an MXL model with attributes decoded as continuous variables (with base level *rare* decoded as 0, *scattered* as 1, *frequently* as 2 and *everywhere* as 3) and interactions between all of them (which we present in the Appendix in Table 6). While acknowledging the simplification introduced by this approach, it nonetheless provides valuable insights into the correlation between diverse small-scale greening measures. Based on these results, our findings indicate a positive relationship between the joint densely-occurring 'build' and 'street' measures, as well as joint densely-occurring 'build' and 'furniture' measures, which may be an indication of complementarity between these attributes. Conversely, no such link between 'street' and 'furniture' measures was found.

3.2. MXL model with interactions

As indicated by the relatively large estimates of standard deviations in the first model, preferences for greening programs are subject to unobserved heterogeneity in preferences and WTP. Socioeconomic and environmental variables are included in the second model to explain differences across the respondents, for which the attribute levels were reduced to only one coefficient per attribute. Table 5 presents the results for the model with interaction terms. The mean coefficients presented in the first row show a similar picture to those of the previous model. It is important to note that the results of the model with interactions start from the base level of the interacting variables and show the effect on the results of respondent characteristics that deviate from this base level. The base in this regard is a respondent who is 30 and 55 years old, has an income in the 2nd-3rd quartile, lives without children, has a heat sensitivity index of below 4 (low or medium), did not receive additional information about the heat-reducing effect of the measures, does not use Vienna's green spaces more than once a week, and lives in a location with more trees and green spaces than the median household, but without a private garden.

The results in Table 5 must be understood against this background. While the interactions with socioeconomic variables cannot be interpreted as causal relationships, they still provide valuable insights into group differences. For instance, it can be seen that a person with the same characteristics as the baseline respondent except for being older than 55 years is less supportive of urban greening programs, as higher age is negatively correlated with the coefficients for both types of greening measures and positively correlated with sensitivity to the cost attribute. On the contrary, respondents younger than 30 years old show a higher willingness to pay for greening programs as they are less sensitive to the cost attribute. However, they exhibit a negative interaction with the ASC, indicating that they are less likely to choose an alternative just for the sake of it. This could be either due to their preference for the status quo or due to the attributes having a stronger influence on their decisions. Net household income also influences preferences towards greening, as a respondent who deviates from the baseline by being in the lowest income quartile is less likely to choose an alternative and has a lower preference for street furniture, while the same respondent in the highest income quartile has a higher preference for greening measures in streetscape. Similarly, respondents with children in their households also exhibit a negative interaction with the ASC and reduced sensitivity to the cost attribute.

Respondents deviating from the baseline respondents by showing a high heat sensitivity index (above 4), as they feel negatively affected by heat in the city, were found to be more willing to pay for green measures, which are also heat mitigating. Further, the WTP rises when the heat-reducing effect of green infrastructure is graphically highlighted. Compared to the baseline respondent, those being considered frequent users of green areas, i.e., those who use Vienna's green spaces more than once a week, show a higher interest in greening programs, as indicated by their higher preferences for measures in streets and reduced sensitivity towards the cost attribute. Even after correcting for the effect of green space usage, we find that the characteristic of respondents living in areas with fewer green amenities (trees and green areas below the median level) correlates with more support for greening programs in terms of WTP. The same is true for owners of private gardens, which could be considered a substitute for publicly provided green spaces. Such respondents are also less sensitive to the cost attribute

4. Discussion

While the results of environmental valuation might be of limited transferability, in part due to the contextual nature of greening benefits (Badura et al., 2021), many of our findings are in line with previous results on citizens' preferences for urban greening. Generally, a clear WTP and preference for greener cities are found across different urban areas on different continents. Like this study, Netusil et al. (2022) in Portland, also find that respondents express the highest WTP for the ASC, which represents a general change independent from the program's attributes. This is because the ASC is often not analyzed separately. Further, aligning with findings from other choice experiments on urban greening, we find that respondents prefer the implementation of measures on streets to those on buildings (Badura et al., 2021; Fruth et al., 2019) and that they express lower WTP for non-greening related attributes, such as street furniture, in our case, fountains in Vienna (Morawetz and Koemle, 2017)[13] or green initiatives in Berlin (Fruth et al., 2019). Moreover, our results may provide preliminary information on complementarity and substitutability. When analyzing the associations between attributes, we found evidence for a positive relationship between the joint densely-occurring 'build' and 'street' measures, as well as joint densely-occurring 'build' and 'furniture' measures, while no such link between 'street' and 'furniture' measures was found.

Our findings regarding socioeconomic influences are also in line with other studies on similar topics. Using the respondents' geo-referenced addresses allowed for a more precise analysis of the characteristics of their place of residence more accurately compared to other studies. However, the finding that the inhabitants of areas with fewer trees and green areas than the median level have a higher WTP for green amenities is also in line with Morawetz and Koemle (2017), who found a lower WTP for additional trees of respondents living in areas with a higher tree density. This is insofar conclusive as inhabitants of areas that are currently undersupplied with green infrastructure can benefit more from greening programs. Further, we find that the heat-reducing effect of small-scale greening measures was particularly considered by the respondents. First, respondents who stated that they were particularly negatively affected by high urban temperatures reported higher WTP compared to baseline respondents with lower scores on the Heat Sensitivity Index. A similar effect was also found in Prague for citizens suffering from negative health impacts caused by high urban temperatures (Badura et al., 2021). Second, highlighting this heat-reducing effect graphically in the DCE, also increases the WTP. It could, therefore, be concluded that by explicitly presenting the various benefits of trees and other plants, including their effect on summer temperatures, city governments could increase the support for greening policies.

Our study reveals an interesting observation regarding scale sensitivity in the context of urban greening. When coding the attribute levels as individual factors, we find that the WTP for changes from *rare* to *everywhere* is not much higher than the WTP for changes from *rare* to

[13] The WTP for fountains even turns negative when bootstrapped fitted values are calculated compared to the interval-mean-based values.

Table 5
Model estimates with systematic taste variation (main effects and interactions with means).

	Main effects		Interactions of mean				
	μ parameter (std. error)	σ parameter (std. error)	Heat Info	Age <= 30	Age >55	Lowest income quartile	Highest income quartile
ASC	3.73***	2.35***	0.22	-1.11***	0.59	-0.88**	-0.75*
	(0.51)	(0.27)	(0.31)	(0.37)	(0.41)	(0.39)	(0.44)
Street	1.28***	1.41***	0.26**	-0.23	-0.33**	-0.15	0.55***
	(0.21)	(0.10)	(0.13)	(0.17)	(0.17)	(0.17)	(0.18)
Build	-0.34**	0.84***	0.22**	0.46***	0.05	0.16	0.13
	(0.16)	(0.09)	(0.10)	(0.13)	(0.13)	(0.14)	(0.14)
Furn.	1.09***	0.99***	-0.02	-0.11	-0.39**	-0.45***	-0.07
	(0.21)	(0.13)	(0.13)	(0.17)	(0.17)	(0.17)	(0.18)
-Cost	-4.34***	3.04***	0.34*	-1.31***	1.01***	0.31	-0.41
	(0.33)	(0.20)	(0.19)	(0.37)	(0.21)	(0.30)	(0.27)
	Interactions of mean						
	Kids living in household	**Self-reported heat sensitive**	**Regular users of UGS**	**Trees < median**	**Green areas < median**	**Owners of gardens**	
ASC	-1.68***	0.54*	-0.34	0.12	-0.40	-0.20	
	(0.51)	(0.33)	(0.32)	(0.32)	(0.32)	(0.40)	
Street	-0.07	0.39***	0.34**	-0.24*	0.04	0.04	
	(0.26)	(0.14)	(0.14)	(0.14)	(0.14)	(0.17)	
Build	0.08	0.18*	-0.06	0.09	0.00	-0.13	
	(0.21)	(0.11)	(0.10)	(0.11)	(0.11)	(0.14)	
Furn.	0.04	0.35**	0.13	-0.08	0.01	0.04	
	(0.27)	(0.14)	(0.13)	(0.14)	(0.13)	(0.18)	
-Cost	-1.54***	-0.83***	-1.17***	-0.38*	-0.58***	-0.53**	
	(0.48)	(0.22)	(0.23)	(0.22)	(0.19)	(0.25)	
Model diagnostics							
LL at convergence			-5652.08				
LL at constant(s) only			-7903.24				
McFadden's pseudo-R^2			0.28				
Ben-Akiva-Lerman's pseudo-R^2			0.52				
AIC/n			1.44				
BIC/n			1.50				
n (observations)			7962				
r (respondents)			1327				
k (parameters)			70				

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ || The main effects of the attributes 'street', 'furn.' and 'build' on which the interactions are based stand for a change from the *rare* level to *frequently* or *rare* to *everywhere,* compared with the baseline of no or only minor changes (*rare* to *scattered*).
The numbers next to the attributes represent the changes in level: 1) rare to scattered | 2) rare to frequently | 3) rare to everywhere.
The parameters are derived from Normal(μ,σˆ2) or Lognormal(μ,σˆ2). The mean for normal distribution is equal to μ, while the mean for log-normal distribution is equal to exp(μ+σˆ2/2).

frequently. Using a Wald test, we test for the statistical significance of this difference and find that the null hypothesis cannot be rejected for the coefficients, which holds for all three attributes. This suggests a potential saturation point where the willingness to pay for additional trees and green facades/roofs may plateau. Based on this finding, further research to understand the dynamics of scale sensitivity could provide valuable insights.

One can calculate the total WTP for hypothetical greening programs in Vienna by combining the annual WTP for the ASC, and those for increasing the density of greening measures on streets and buildings and for additional street furniture. Considering a change of each attribute from *rare* to *frequently* results in a combined WTP of 17.74€ per inhabitant per year. City-wide, this would accumulate to an annual budget of 34 million Euro (or more than 27 million Euro if only the age classes covered by the survey are considered). To put these figures in perspective, the current annual budget of the city's Magistrate Department 42 (MA42, Wiener Stadtgärten), which is responsible for planning, constructing, and maintaining all green spaces, street trees and parks in Vienna, is 25 million Euro (City of Vienna 2023b). However, while our results clearly show a general support of Vienna's population for greening programs, it must be acknowledged that the results cannot be directly used to inform financial decisions.

Issues that limit this ability of the DCE results include that respondents may not have considered alternative uses of the fees collected that they might prefer or side effects of the proposed programs in their decision heuristics, such as a reduction in parking spaces needed to implement streetscape greening, even though they would raise the issue in a political process. Furthermore, it is possible that respondents viewed the proposed greening programs as unrealistic, e.g., due to the scale of the measures, or that real-world constraints on city-wide greening, such as property rights or technical issues, were not sufficiently addressed in the information materials, which would undermine the coerciveness of the DCE and affect the economic interpretation of the WTP estimates.[14] Qualitative instruments, such as the ones that were used in the choice experiment, could be used to better explore citizens' perceptions of city-wide greening programs. Further, it is essential to note that our study did not incorporate the real costs associated with implementing and maintaining a city-wide greening program in the choice experiment. While the information on the MA42 budget gives an insight into the ongoing financing of urban green, a deeper understanding of the true costs is needed. This will be instrumental in ensuring the successful implementation of measures. Despite these constraints, the analysis remains valuable for estimating public support and facilitating comparisons between different greening options, contributing to a more informed and nuanced discussion within the realm of urban planning and policy.

5. Conclusion

Today's green infrastructure is unequally distributed within cities, which is also the case in Vienna, a city that is generally perceived as green (Brenner et al. 2022). Against the background of rising urban temperatures and densification processes, small-scale greening measures in streetscapes and on buildings are needed to improve the urban climate and aesthetics in densely built areas that are currently undersupplied with green infrastructure. Since implementing these measures on a sufficient scale requires political will and significant resources, it is crucial to understand citizens' preferences regarding the design of greening policies, group differences and how they value the benefits of urban greening. In contrast to previous research that has focused primarily on individual measures and limited case study streets with small sample sizes, our approach utilizes a Discrete Choice Experiment to investigate urban greening more broadly. We compare two different types of greening measures and leverage a substantial and representative sample of Vienna's population.

Our results show an overall support for small-scale measures, a general wish to implement a greening scenario over the status quo and a relative preference of street trees and planters over green roofs and facades. Additionally, we examine the correlation between attributes, which provides preliminary information about complementarity and substitutability. In a model that examines associations between attributes, we find that respondents prefer joint densely occurring 'build' and 'street' measures, as well as joint densely-occurring 'build' and 'furniture' measures. Conversely, no preference for joint densely occurring 'street' and 'furniture' measures was found. Further, by introducing interactions with socioeconomic variables, selected attitudes, and neighborhood characteristics based on geo-referenced addresses, we find characteristics such as younger age, higher income, a higher sensitivity and green space usage frequency that positively correlate with higher WTP. Moreover, respondents who live in districts that are relatively deprived of urban green are likely more willing to support greening measures. When combining the WTP for the attributes with each other for a medium greening scenario, it already exceeds the annual budget of Vienna's magistrate's department responsible for urban green. Despite this, methodological and conceptual issues of choice experiments such as the one used in this study limit the ability of the results to directly guide financial decisions.

Moving forward, the significance of our findings lies in providing valuable insights into citizens' preferences and support for greening programs that can inform the development and refinement of urban greening policies. The challenge ahead involves navigating practical, technical, and political obstacles in the implementation of these programs, ensuring that the support expressed by Vienna's population can be translated into effective and sustainable urban greening initiatives.

Funding

This research was funded by the Vienna Science and Technology Fund (WWTF) under the Environmental Systems Research 2020 - Urban Regions – call, and conducted as part of the SENSUS project (The social equality of Nature-based Solutions to urban heat stress), grant number ESR20-011.

CRediT authorship contribution statement

Antonia Elisabeth Schneider: Conceptualization, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Tatjana Neuhuber:** Conceptualization, Writing – original draft. **Wojciech Zawadzki:** Methodology, Software, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Antonia Elisabeth Schneider reports financial support was provided by Vienna Science and Technology Fund.

Acknowledgements

The authors acknowledge TU Wien Bibliothek for financial support through its Open Access Funding Programme.

[14] At this point we want to thank an anonymous reviewer for pointing out the issues of coerciveness and consequentiality, motivating the discussion on the complexities involved in translating experimental findings into real-world policy implementation.

Appendix

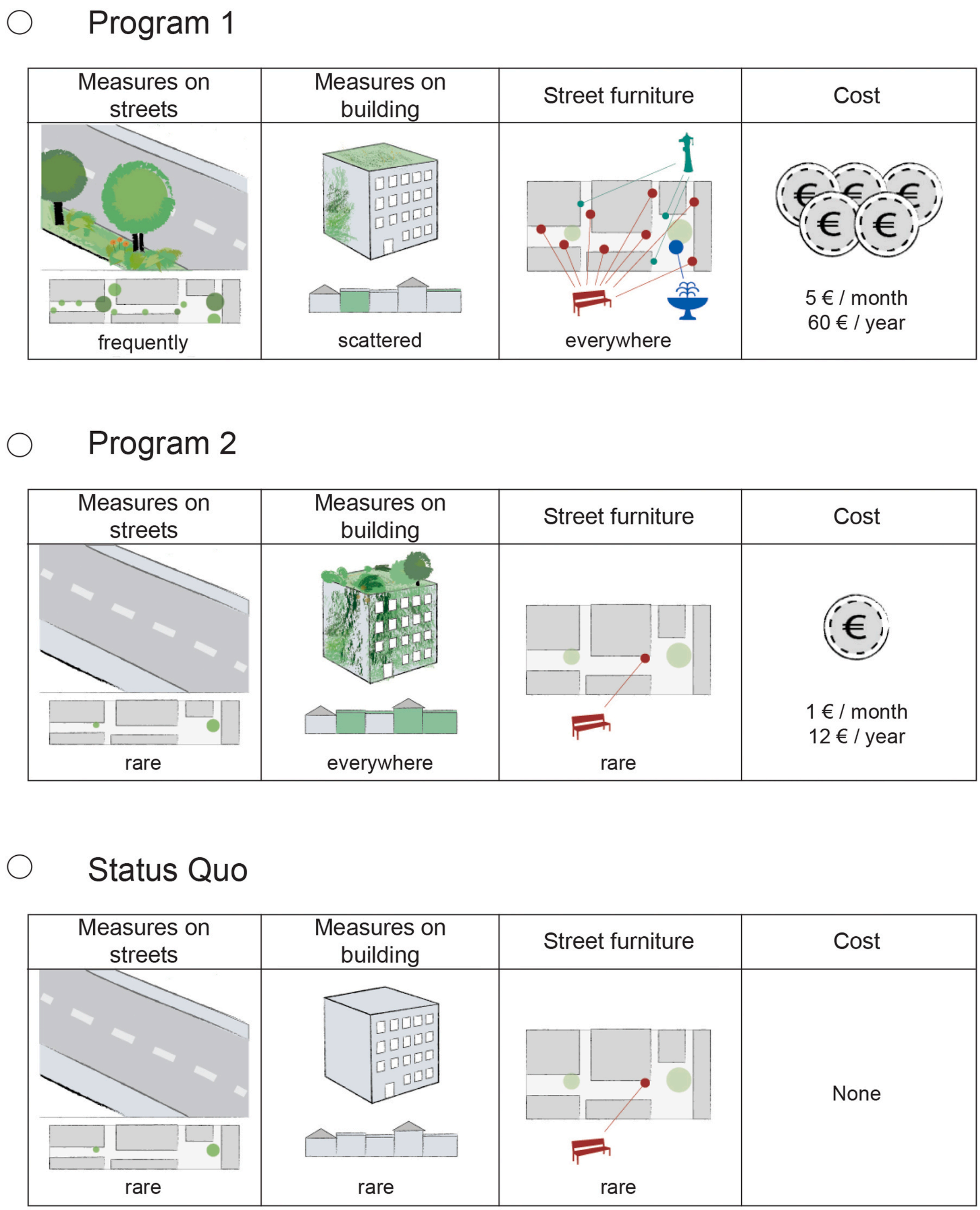


Fig. 1. Example of a choice card (translation)

Table 6
Mixed logit model estimates with attribute interactions

		In preference space	
	Dist.	μ parameter (std. error)	σ parameter (std. error)

(continued on next page)

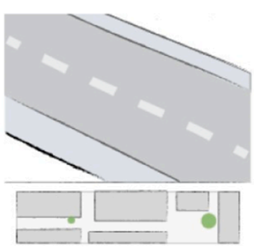
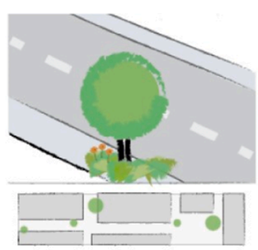
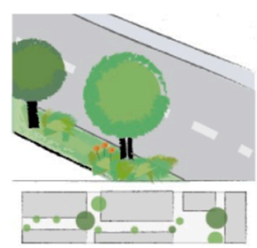
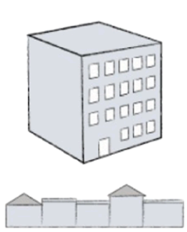
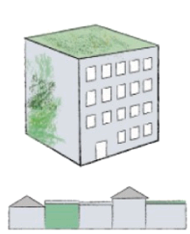
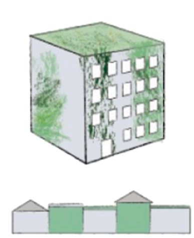
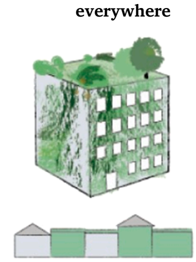
Table 6 (*continued*)

		In preference space	
ASC	norm	4.95***	3.28***
		(0.41)	(0.44)
Street	norm	0.31***	0.45***
		(0.10)	(0.17)
Build	norm	-0.18*	0.74***
		(0.10)	(0.15)
Furniture	norm	-0.15*	0.53**
		(0.09)	(0.22)
Street X Build	norm	0.26***	0.45***
		(0.06)	(0.06)
Street X Furniture	norm	0.01	0.14***
		(0.04)	(0.04)
Furniture X Build	norm	0.15***	0.38***
		(0.04)	(0.09)
Cost	log-norm	-5.80***	3.26***
		(0.27)	(0.22)
Model diagnostics			
LL at convergence		-5630.83	
LL at constant(s) only		-7903.24	
McFadden's pseudo-R^2		0.29	
Ben-Akiva-Lerman's pseudo-R^2		0.52	
AIC/n		1.43	
BIC/n		1.46	
n (observations)		7962	
r (respondents)		1327	
k (parameters)		44	

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The parameters are derived from Normal(μ,σˆ2) or Lognormal(μ,σˆ2). The mean for normal distribution is equal to μ, while the mean for log-normal distribution is equal to exp(μ+σˆ2/2).

Table 7
Explanation of the attribute levels as they were provided to the respondents

rare	scattered	frequently	everywhere
			
There are many streets without greening. There is a tree in front of some houses.	The number of trees and plant troughs will be increased slightly. There is a tree in front of every fourth house.	The number of trees and plant troughs is considerably increased. There is a tree in front of every second house.	The number of trees and plant troughs is increased significantly. There is a tree in front of almost every house.
Rare	**scattered**	**frequently**	**everywhere**
			
Green roofs and façades are a rarity.	Every third building that is suitable for greening is greened.	Every second building that is suitable for greening is greened.	Every building that is suitable for greening is greened.
Rare	**scattered**	**frequently**	**everywhere**

(*continued on next page*)

Table 7 (*continued*)

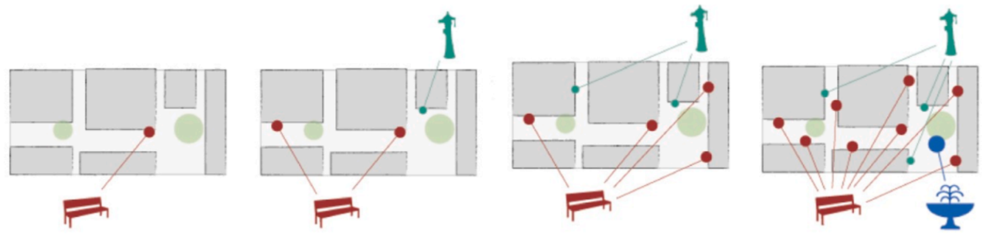
rare	scattered	frequently	everywhere
			
There are a few benches and drinking fountains.	Additional benches will be installed so that they can be reached within 5 minutes from every house. Drinking fountains are installed at a few selected locations.	Additional benches are installed so that they can be reached in 3 minutes from every house. Drinking fountains and water sprinklers are installed in squares and in some streets.	Additional benches are installed so that they can be reached in 1 minute from every house. Many drinking fountains and water sprinklers and a few fountains will be installed.

Table 8
Wald test

Wald test (null hypothesis)	t	p-value	
b_street1==b_street2	50.31	0.000	***
b_street1==b_street3	34.58	0.000	***
b_street2==b_street3	1.24	0.266	
b_furniture1==b_furniture2	8.77	0.003	***
b_furniture1==b_furniture3	7.07	0.008	***
b_furniture2==b_furniture3	0.01	0.920	
b_build1==b_build2	16.21	0.000	***
b_build1==b_build3	29.37	0.000	***
b_build2==b_build3	0.66	0.418	

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