The dilemma of urban green spaces: Improved ecosystem services or smooth traffic?

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Abstract

Cities concentrate almost 60% of the world's population. Worldwide, urban populations are highly vulnerable to climate change. Urban green spaces and related ecosystem services help increase inhabitants' quality of life and well-being and mitigate the impacts of climate change. Otherwise, in terms of urban planning, green spaces can raise a dilemma by reducing the space available for vehicle traffic and parking. In this paper, we focus on green spaces around the tram network in the *Lyon* metropolitan area, France, to assess the social demand for the greening of the urban transport infrastructure, using a Discrete Choice Experiment (DCE). The survey was conducted in 2022 with 500 inhabitants. Our results show that respondents are in favor of urban greening due to its capacity to reduce air temperature and increase biodiversity. However, they are, on average, against a high reduction of the available space for traffic and parking, as a result of urban greening development. Outcomes also demonstrate a high heterogeneity in inhabitants' preferences partly driven by their sensitivity and commitment to the environment.

Keywords : Urban greening, Urban ecosystem services, Urban traffic, Transport infrastructure, Choice experiment.

Jel codes : D12, Q57, Q58

1 Introduction

In 2020, cities concentrated almost 60% of the world's population and more than 80% of the population in France [1]. At the same time, cities are highly vulnerable to climate change (heat waves, floods, air pollution). They, therefore, face increasing challenges in terms of urban planning strategies to preserve the well-being of urban populations (Revi & IPCC, 2014; Wolch *et al.*, 2014).

Urban green spaces (UGS), such as urban parks, periurban forests, street trees, green walls, and their related urban ecosystem services (UES)[2] allow to meet many needs of the inhabitants in terms of quality of life (Revi & IPCC, 2014). For example, UGS can improve landscape aesthetics, air quality, and cooling (Aram *et al.*, 2019), encourage recreational activities (Arnberger & Eder, 2011) and social interactions (Jennings & Bamkole, 2019), or reduce urban noise (Rey Gozalo *et al.*, 2017).

In this paper, we focus on urban public transport, particularly the tram network, as a means of renaturing and revegetating the city. The tram network in France increased by 545% between 1990 and 2014, becoming, ahead of the metro and the suburbs, the leading rail transport network (in kilometers) in urban areas (CGDD-SOeS & Paquel, 2016). Tram infrastructures and their rights of way offer opportunities for converting urban artificial areas to green ones, thus increasing the supply of UES and enhancing the livability of cities. However, the increase in urban green areas will reduce the available space for vehicle parking spots and road traffic, which may worsen traffic jams. Thus, there is a trade-off between more UES from green transport facilities and increased land constraints for private mobility.

This land use conflict has been observed in Paris with the actions of mayor Anne Hidalgo. Her first mandate had been marked by a standoff over the pedestrianization of the Seine riverbank routes. For her second, she is tackling a decrease in road traffic throughout downtown Paris. Low emission zones in Barcelona have also lead to land use conflicts. For instance, Oltra *et al.* (2021) show that more individuals owned a car among opponents to the low emission zone project than among supporters (80% and 62%

[1] https://donnees.banquemondiale.org/indicator/SP.URB.TOTL

[2] Urban ecosystem services include: urban cooling, reduction of NOx concentration, urban flood risk mitigation, storm-water runoff retention, carbon sequestration, scenic/landscape quality provision, crop pollination, sediment retention, reduction of olfactory pollution, sound barrier, cultural and recreational services, support to productive activities (urban agriculture, nursery), etc.

respectively)

Our study focuses on the social demand for greening the tram network in the *Lyon* metropolitan area, France. This case study represents an interesting case study since the municipality has undertaken a recent Mobility Plan 2021–2026 to strengthen territorial cohesion by serving four priority districts with extensions of the tram network. Our objective is to measure the preferences of the inhabitants, *i.e.* their willingness-to-pay (WTP) for the greening of the tram network with the Discrete Choice Experiment (DCE) valuation method. For this purpose, we use the answers of 500 respondents in a representative survey conducted in *Lyon* metropolitan area in 2022. Apart from estimating of the average WTP, we also analyze the determinants of individual heterogeneity in WTP, such as the location of the residence, frequency in the use of public transport, car ownership, etc. This will help to understand the potential reluctance of inhabitants and the social acceptability of green tram network in *Lyon*, helping in fine to guide the design of local public policies. To the best of our knowledge, there is no research on the social demand for UES related to urban public transport and their rights of way planning (See section Literature).

The paper is organized as follows. Section 2 presents the literature on the measurement of UES. Section 3 describes the case study area. Sections 4 and 5 present the design of the DCE and the econometric framework. Section 6 provides the descriptive statistics and econometric results from different models. Section 7 concludes with a summary of the main results.

2 Literature

Land-use land-cover changes models and mapping, are designed to simultaneously estimate and map the supply, *i.e.* the biophysical flows of UES in each land-use type and the related economic costs (avoided cost, social cost, etc.), and the demand of UES by the number of beneficiaries, which include the total population within and close to the study area. De Valck *et al.* (2017), assesses the supply of UES in terms of biophysical flows and the avoided costs in the case of brownfield redevelopment in Flanders (Belgium). They show that the value of recreation far exceeds other values, including the value of avoided runoff. Cortinovis & Geneletti (2020) developed two tools assessing urban transformations, one on the supply and the other on the demand of UES. These models were tested on seven UES in Trento, Italy. This spatially explicit value aggregation approach estimates the total economic value associated with different development projects. Nevertheless, it estimates the potential benefits of environmental goods and services but does not allow for the evaluation of individual demand linked to the socio-demographic characteristics of individuals and the social demand for each UES. In this sense, revealed or stated preference methods are used to evaluate the social demand for UGS.

Through the hedonic price method, many studies have shown the benefits associated with proximity to UGS, depending on their type (forest, park, cemetery) and their size and location (Morancho Bengochea, 2003; Czembrowski & Kronenberg, 2016; Liebelt *et al.*, 2019). The results are unanimous and show positive and significant WTP for proximity to green spaces in urban areas.

Complementing hedonic studies, several discrete choice experiments (DCE) have found positive WTP to benefit from different types of UGS such as: green walls (Collins *et al.*, 2017; Fruth *et al.*, 2019), green roofs (Vanstockem *et al.*, 2018) and street trees (Giergiczny & Kronenberg, 2014; Ng *et al.*, 2015; Soto *et al.*, 2018; Fruth *et al.*, 2019; Dongen & Timmermans, 2019; Mokas *et al.*, 2021; Welling *et al.*, 2022) or different naturalness (Bronnmann *et al.*, 2020). These studies describe UGS with landscape attributes which include : type of land use (grassy/wooded area, presence of water, etc.), type of vegetation (shrub, tree, flower bed; endemic species or not, etc.), diversity of plant species, and density of vegetation (ratio of vegetation to building).

Using DCE, other studies are more specific to UES. In a DCE conducted in Austria, Arnberger & Eder (2011) assessed preferences for recreational amenities, introducing congestion effect (number of joggers, walkers, bicyclists or dogs) and cleanliness (litter or not) in urban parks. Their results show that preferences depend on the age of the individual interviewed. In the same way, Kim *et al.* (2020) and Vollmer *et al.* (2016) assess preferences for different cultural and recreational facilities, respectively in Northern Japan's Sapporo city and on riverbanks in Jakarta in Indonesia. Liu *et al.* (2020) show positive WTP for proximity to neighborhood parks, central city parks, or national parks in Beijing. They then investigate how air pollution can explain WTP heterogeneity. The results show that respondents exposed to high air pollution have a higher WTP for the presence of an additional national park than others. Using a non-economic evaluation method with a survey in four European cities (Berlin, Stockholm, Rotterdam and Salzburg), Bertram & Rehdanz (2015), ordered the preferences of individuals in terms of the services provided by UGS: neatness comes first, followed by naturalness, spaciousness and sociability. Last but not least, in Singapore, Jaung *et al.* (2020) used a DCE to study social preferences for five UES : change in air pollution (in %), temperature reduction (in °C), noise abatement (in dB), biodiversity conservation (more five bird or butterfly or plant species), and community programs that provide cultural benefits (nature education program, community garden program, therapeutic horticulture program). The results showed that urban people value UGS allowing to reduce temperatures, and air pollution and connect to nature. Nevertheless, there is no significant effect of reducing noise and increased biodiversity in the city.

While many studies have quantified a positive WTP for UGS proximity and related landscape attributes, few are directly related to the WTP to benefit from UES (Arnberger & Eder, 2011; Jaung *et al.*, 2020; Liu *et al.*, 2020; Jin *et al.*, 2020). Shortcomings remain in this field due to the lack of evaluation of preferences for multiple ecosystem services in the case of UGS.

Among the UGS, urban transport is becoming increasingly important in cities. Transport infrastructures and their rights of way are key elements of the urban landscape and the question of their sustainable design and planning is becoming central for decision-makers. They constitute a great opportunity for conversion to urban green areas that can provide ecosystem services and enhance cities' livability. However, to our knowledge, there is no research on the social demand for UES related to urban transport infrastructures.

Our study focuses on the social demand for the renaturation of industrialized and highly anthropized urban landscapes to restore ecosystem services provided by soils through the development of transport infrastructures and their rights-of-way (e.g. road, rail, streetcar, underground and aerial networks - water, electricity, gas and rivers). The challenge for urban socio-ecosystems (Chapin III *et al.*, 2009) is to find a sustainable balance between land-use planning, in this case transport infrastructures, the maintenance of ecological functions provided by soils and biodiversity (UES supply) and the development of urban nature and ecosystem services for human well-being (UES social demand).

In this context, the Discrete Choice Experiment (DCE) valuation method can be used to inform the planning decision process, mainly because of its flexibility and ability to take into account the multidimensional aspects of UES, and to provide detailed information on marginal changes as well as preferences between the attributes themselves and between the scenario attributes and the monetary attribute (Adamowicz *et al.*, 1998; Hanley *et al.*, 2001; Bateman *et al.*, 2002). Thus, DCE is one of the most appropriate methods to value social preferences for environmental and urban planning (Hoyos, 2010).

3 Case study : Canopy Plan and urban transport infrastructure in the *Lyon* metropolitan area

The canopy of the *Lyon* metropolitan area was estimated at 27% of the territory's surface area — 529.4 km^2 for the 59 municipalities in 2009. This represents more than 2 million trees. However, access to green spaces is unevenly distributed across the territory. The environmental health diagnosis of the *Lyon* metropolitan area (Anzivino *et al.*, 2018) shows that the municipalities located in the south (Saint-Fons and Feyzin) of the metropolitan area are frequently subject to odor and noise nuisances, which affect both residents of industrial areas and the inhabitants of the city center. These nuisances can be explained by the local climatic context (topography and prevailing winds favoring the dispersion of pollutants), but above all, by the presence of major industries (e.g., refineries, chemical industries, and wastewater treatment plants) and transport infrastructure crossing the territory.

Initiated in 2017, the Canopy Plan is the operational strategy of the Tree Charter (2011). It is a partnership-based territorial mechanism involving more than 120 public, private and associative stakeholders in the *Lyon* metropolitan area, with a dedicated urban service. The Canopy Plan proposes concrete actions, quantified objectives, and resources for adapting to climate change as recommended by the *Lyon* metropolitan area Climate Plan. This plan thus reflects the convergence of objectives between these two approaches: climate and biodiversity. The Canopy Plan considers the tree as a guide principle for protecting and restoring ecosystems and landscapes, and for territorial dynamics. Updated in 2020, the Canopy Plan is based on four major strategic axes: (i) to perpetuate and develop the tree heritage, (ii) to improve the health and mobilization of citizens, (iii) to federate professionals around the Canopy Plan, and (iv) to develop research and innovation for the Canopy.

In the regional Mobility Plan, the implementation projects for 2021–2026 [3] strengthen territorial cohesion and support the projects of the New Urban Renewal Program based on extensions of the tram network. Four new lines representing nearly 25 km of tracks

[3] https://www.sytral.fr/611-les-realisations.htm

will be created, offering connections with major lines of existing metros and trams. The Mobility Plan also includes improvements in the bus and metro network.

The Mobility Plan and the Urban Travel Plan (2017–2030)[4] have an ambition to create a real alternative to private cars and increase the use of public transport and soft mobility (bicycle and walking). To achieve this challenging target, reviewing the space allocated to cars, parking, and street roads is needed. For the *Lyon* metropolitan area, the individual car remains the primary mode of transport, including for short distances. Thus, the car represents 59% of travels between 3 and 5 km. This transport occupies up to 80% of public space and its use is almost exclusively individual. This is particularly true for home-work commuting, where the average vehicle occupancy rate is 1.06 [5].

The vegetation of the extensions of trams in the metropolitan area could contribute to the Canopy Plan, offering the opportunity to transform the landscape by providing a green infrastructure and restoring UES at the city scale. Reinforcing this new dimension of the tram and strengthening its network and attractiveness could encourage the acceptability of the implied land use change (increase in green space at the expense of the space for individual vehicles).

4 The steps of the Discrete Choice Experiment

4.1 Choice of the attributes and levels

The DCE is a stated preference evaluation method that is widely used to model preferences for UGS and their related UES. In DCE surveys, ecosystem services are defined by a number of attributes and their levels. The combination of these attributes and levels generates different situations called choice sets. Each choice set comprises two to three alternatives describing hypothetical changes in the ecosystem services to be assessed. Respondents are then asked to choose their most preferred alternative within each choice set. By including a payment mechanism as one of the attributes, WTPs can be inferred from people's choices. In this paper we use the DCE to measure the social demand for the development of UES *versus* the reduction of space available to traffic and parking.

[4]https://www.sytral.fr/306-presentation_pdu.htm

[5]https://destinations2026-sytral.fr/processes/plandemobilite

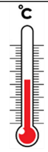
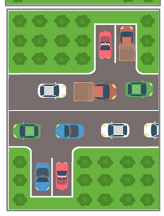
Attributes	Description	Levels	Illustrations
Shade and cool zone Temperature drops during hot weather	In periods of high heat, vegetation helps to reduce the air temperature and provides shade.	-0°C, -1°C et -2 °C	
Bird abundance Increase in the number of birds (of different species)	Vegetation helps to preserve and restore biodiversity in urban areas. The abundance of birds is an indicator of this biodiversity.	+0%	
		+5%	
		+20%	
Traffic and parking Reduction of available space around the tram	The vegetation around the tramway reduces the space available for roads and parking spaces.	« No reduction »	
		« Low reduction »	
		« High reduction »	
Cost Increase of monthly local tax	Increase in € per month and for your whole household of your local taxes.	+0€, +1€, +4€, +10€	

Figure 1: Attributes description

The selection process of our attributes and their levels was based on three main steps. Firstly, a literature review of studies assessing changes in the demand for UES. Following this step, we selected an extended list of potential attributes and levels to measure these changes. Secondly, we conducted three focus groups at the *Lyon* metropolitan area (first with experts on urban planning, environmental management and the public transport network, second with students in real estate management, and third with inhabitants). In these focus groups, we were able to narrow down the extended list of attributes. Participants also suggested new attributes. The levels of all attributes were also discussed with participants. Thirdly, a pilot study/survey was conducted with a total of 20 inhabitants to test the understanding of the chosen attributes and the relevance of their levels. The selected attributes and their levels following these steps are presented in Figure 1 .

The first attribute, *shade and cool zone*, corresponds to the impact of urban vegetated areas on temperatures during heat waves. The vegetation within these areas can create shade to shelter from the increasing summer temperatures and have a cooling effect during the summertime. We have determined three possible levels for this attribute: -0°C (reference level), -1°C, and -2°C. The choice of these levels was based on the average effects of linear vegetation on the reduction of high temperatures in cities (Hamada & Ohta, 2010; Huang *et al.*, 2018; Aram *et al.*, 2019),

The second attribute, *bird abundance*, relates to the impact of UGS on the health of urban biodiversity. One of the core indicators used to observe this impact in the literature is the diversity and abundance of birds (Caula, 2007; Pellissier *et al.*, 2013; Dupuis *et al.*, 2014). Three levels were defined to measure changes in this attribute: +0% (reference level), +5%, and +20% of species and individuals. These levels were chosen mainly based on our literature review of attributes and levels. However, expert opinion, from environmental association for the protection of birds, was also sought for confirmation.

The third attribute, *traffic and parking*, is linked to the impact of UGS on urban traffic and the reduction of available parking areas. This attribute represents the trade-off urban planners make regarding the distribution of urban areas between greening areas (and, therefore, pedestrian space) and automobile traffic and parking. We have defined three qualitative levels of reduction of this space: no reduction (reference level), low reduction, and high reduction.

The fourth attribute, *cost*, is the monetary attribute. It is the willingness to pay in terms of additional monthly local taxes (increase in € per month and for the whole household) for the different proposed tram greening scenarios. The levels chosen to represent the increase in the local tax are 0€ euros which corresponds to the reference level, 1€, 4€ and 10€ per month. The choice of these levels was based on the level of local taxes in high-income countries, and the level of local taxes in the *Lyon* metropolitan area. Studies assessing UGS and UES have used multiple forms of monetary attributes (Bronnmann *et al.* (2020) : increase in rent; Fruth *et al.* (2019) : annual contribution to an urban green fund; Collins *et al.* (2017) : cost directly associated with green wall; Jaung *et al.* (2020) : increase in monthly charges related to the maintenance of common residential areas and in particular cleaning; Kim *et al.* (2020) : surcharge associated with development costs; Vanstockem *et al.* (2018); Vollmer *et al.* (2016) : green roof installation costs/m² or maintenance fee). Yet, monthly taxes is the most used type of payment mechanism used in UES literature (Giergiczny & Kronenberg (2014) also used the monthly increase in local taxes; Liu *et al.* (2020) : exceptional tax associated with the creation of a park; Ng *et al.* (2015) : extra local environmental tax; Soto *et al.* (2018) : monthly utility tax according to the maintenance costs of green spaces).

All these attributes, their description, their levels and their visual representation are presented in Figure 1.

4.2 Implementation of the DCE

We have used the *Ngene* software (Rose *et al.*, 2010) to generate the choice cards required for the DCE. The full-factorial design produces a high number of choice sets; therefore, we used an efficient design to reduce the number of possible choice sets to 12, equally divided into two blocks.

Preliminary choice sets were first produced using standard priors. These choice sets were used in the pilot study (20 respondents, corresponding to 120 choices). The data collected from this study was analyzed and helped define new priors, which were then used to generate the final experimental design. We do not use the data collected in the pilot in our final analyses.

In our experimental design, each choice set includes two hypothetical alternatives: "Alternative 1" and "Alternative 2". A third alternative was included in the choice cards as a "status-quo" (SQ) option, which corresponds to the current situation. This option is essential for theoretical and estimation reasons. The levels chosen to define this option are the reference levels for all attributes. Figure 2 presents an example of a choice card.

Respondents have been randomly assigned to a particular block. Within each block, the six choice cards are successively proposed in random order to respondents who make six choices between two different greening scenarios.

The questionnaire for the survey was designed in four different sections. The first section concerns respondents' socio-economic profiles and the second deals with the respondent's current practices towards and perceptions of urban greening and public transport. The third is dedicated to the DCE design, and finally, the fourth aims to control the bias in the study. Given the hypothetical nature of the used method, the DCE, respondents may overstate their willingness to pay (WTP) / willingness to accept (WTA). The high cognitive burden put on them can affect their ability to understand the different situations presented to them and lead to biased responses. And in some instances, respondents may not answer truthfully due to social desirability. Thus, in the fourth section, we ask related questions to distinguish biased responses.

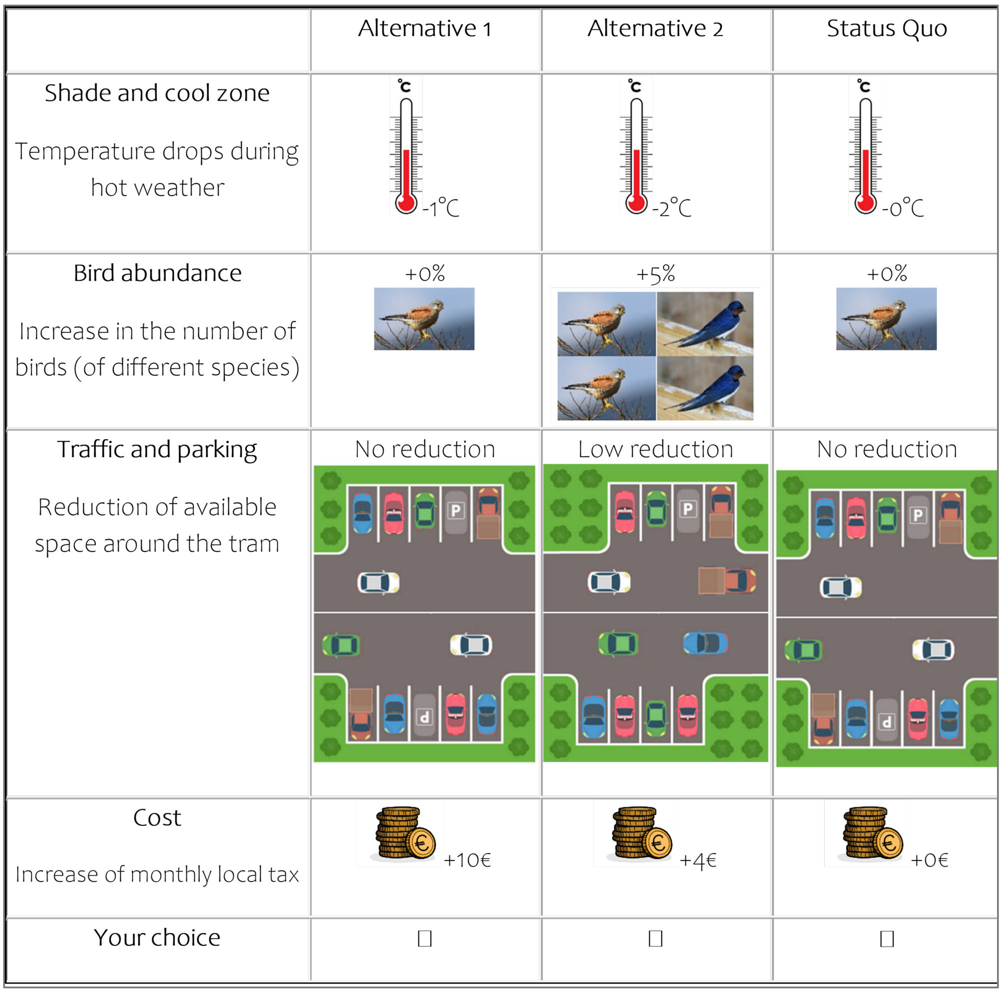


Figure 2: Example of a choice card

Two videos were made to accompany the questionnaire. The first video describes the context of the study. It, also, focuses on urban greening and stakeholders (researchers, as well as urban and transport planners) to enhance the political consequentiality of the study. The second explains the experimental design with a simplified way for non-expert people and defines the attributes, their levels, and their illustration in great detail. These videos are one of the techniques that can be implemented before the choice experiment to reduce the hypothetical and informational bias (Colombo *et al.*, 2022; Chowdhury *et al.*, 2010).

In may 2022, the final questionnaire was sent to a panel of more than 4,000 respondents, inhabitants of the *Lyon* metropolitan area, by a French polling organization [6].

5 Econometric background

We rely on the Random Utility Model (RUM) in which an individual choice results from the maximization of the relative utility derived from the different alternatives (McFadden, 1974). Respondents choose the alternative providing the highest expected utility. The RUM model assumes that individual i ($i = 1, ..., I$) chooses among j ($j = 1, ..., J$) possible multi-attribute vegetation scenario and that the associated utility U_{ijt} from alternative j in choice card t ($t = 1, ..., T$) is:

$$U_{ijt} = V_{ijt} + \epsilon_{ijt} \tag{1}$$

where V_{ijt} is the indirect utility from choosing vegetation scenario j, and ϵ_{ijt} is the error term capturing the unobserved utility.

5.1 Random parameter logit

To account for the unobserved heterogeneity in taste and preferences, we consider the mixed logit (ML) model also referred to as random parameter logit (RPL) model (McFadden & Train, 2000). In the RPL model, individual i's utility ($i = 1, ..., I$) from choosing alternative j ($j = 1, ..., J$) in choice card t ($t = 1, ..., T$) is:

$$U_{ijt} = \beta_i X_{ijt} + \epsilon_{ijt} \tag{2}$$

where X_{ijt} is a vector which includes the attributes of the alternative, β_i terms are the associated random parameters, and ϵ_{ijt} is an IID extreme value. To capture the specific nature of the status quo option in the DCE, X_{ijt} includes an alternative-specific constant (ASC) related to the status quo: SQ is a dummy variable equal to one in the status quo alternative and to zero otherwise in all the choices.

[6] The company BVA (https://www.bva-group.com/). This company complies with the rules of ethics and deontology in data collection and respects the protection of personal data

By estimating the RPL model represented by Equation (2), it is possible to compute the mean WTP for attribute x:

$$WTP_x = \frac{-\beta_x}{\beta_{cost}} \tag{3}$$

where β_x and β_{cost} are the parameters associated with attribute x and the monetary attribute (*i.e.*, the additional tax) respectively. To facilitate the calculation of the WTP, we estimate a RPL model where the monetary attribute is fixed whereas all other parameters are specified as random parameters. This approach is a standard practice in the literature when conducting a DCE (Gillich *et al.*, 2019; Chèze *et al.*, 2020).

5.2 Latent class model

Similarly to the RPL model, the latent class model (LCM) has two main advantages compared to the Conditional Logit : (i) it allows for heterogeneity - in other words, it assumes that parameters (i.e., β's) can vary from one individual to another - which is useful to take into account individual specificities and (ii) it frees from the IIA assumption (Dahlberg & Eklöf, 2003; Brownstone & Train, 1998). However, contrary to the RPL model, the LCM frees from making assumption on the distribution of preferences among the population. Instead, it allows for unobserved preference heterogeneity with membership in latent classes of preferences. It relies on the assumption that the population is divided in Q subgroups (or classes). Individuals in a given class are assumed to have homogeneous preferences, but these preferences differ from individuals belonging to other classes (Pacifico & Yoo, 2013). The probability that individual i chooses alternative j in the choice situation t given that he belongs to class q is :

$$P(y_{it} = j | class = q) = P_{it|q}(j) = \frac{exp(X'_{ijt}\beta_q)}{\sum_{j=1}^{J} exp(X'_{ijt})\beta_q}$$

For a given class q, individual i's contribution to the likelihood would be :

$$P_{i|q} = \prod_{t=1}^{T}\prod_{j=1}^{J}(P_{it|q})^{y_{ijt}}$$

where y_{ijt} is a binary variable equal to 1 if agent i chooses alternative j in scenario t, and equal to 0 otherwise.

Class assignment is unknown. Greene & Hensher (2003) note H_{nq} the prior probability that individual i belongs to class q :

$$H_{iq} = \frac{exp(z'_i\theta_q)}{\sum_{q=1}^{Q} exp(z'_i\theta_q)}, q = 1, ...Q, \theta_Q = 0$$

where z_i is a set of observable agent-specific characteristics which impact class membership, like socioeconomic characteristics, and θ_q are class membership model parameters. The likelihood for individual i is :

$$P_i = \sum_{q=1}^{Q} H_{iq} P_{i|q}$$

The log-likelihood for the sample is :

$$ln(L) = \sum_{i=1}^{N} ln(\sum_{q=1}^{Q} H_{iq} P_{i|q})$$

Individual-specific estimate

After estimating θ_q, we can obtain, for each individual, the probability that he/she belongs to class q given her answers to the choice sets. The posterior membership probability is estimated as follows :

$$\hat{H_{q|i}} = \frac{\hat{P_{i|q}} \hat{H_{iq}}}{\sum_{q=1}^{Q} \hat{P_{i|q}} \hat{H_{iq}}}$$

Influence of auxiliary variables on class membership

The latent class model identifies homogeneous groups in terms of individuals' preferences for the different attributes characterizing a good or service. It can be assumed that certain socioeconomic variables influence the membership of individuals in these groups. To find out this influence, we regress the posterior probability $\hat{H_{q|i}}$ on A auxiliary variables:

$$log(\frac{\hat{H_{q|i}}}{1 - \hat{H_{q|i}}}) = \beta_1 X_1 + ... + \beta_A X_A$$

6 Main results

6.1 Descriptive statistics and sample representativeness

Out of a panel of about 4150 inhabitants of the *Lyon* metropolitan area, contacted to answer our survey, 500 respondents completed the questionnaire which correspond at a response rate by 12%. Table 1 presents the statistics of the sample.

By using a panel of respondents constructed by the polling institute, we observe that initial sample was close to a socio-economic and demographic representativity of the population of the *Lyon* metropolitan area. However, to obtain a complete regional representativeness, we adjust our sample according to the data from the French National statistics in 2015 at the metropolitan area geographic scale. For gender, age, socio-professional categories (SPC) and location (city center *versus* suburb), Table 1 shows the statistics of the initial non weighted sample (*non-weighted sample* column) and that of the population census which correspond to the final weighted sample (*weighted sample* column).

Table 1: Sample Descriptive statistics

	Non-weighted sample	%	Weighted sample	% *
Gender				
Homme	199	39,8%	233	46,6%
Femme	301	60,2%	267	53,4%
Age				
18-34	84	16,8%	175	35,0%
35-49	158	31,6%	124	24,7%
50-64	144	28,8%	102	20,5%
> 65	114	22,8%	99	19,8%
Socio-Profesionnal Categories **				
SPC +	177	35,4%	178	35,5%
SPC -	141	28,2%	133	26,7%
Inactive	182	36,4%	189	37,8%
Location				
City center	173	34,6%	195	39,0%
Suburb	327	65,4%	305	61,0%
Total	500	100,0%	500	100,0%

* Source : French National statistics, INSEE RGP 2015

** SPC + : Farmer / Craftsman, trader, company manager, self-employed / Executive, intellectual profession, liberal profession ; SPC - : Employee / Worker; Inactive : Retired / Student / Inactive person (at home, looking for a first job...)

Using the follow-up questions in section 4 of the questionnaire, we removed a total of 20 respondents, considered as *protest answers* and respondents who declared that they did not understand the DCE. Concretely, to those who have always chosen the SQ we asked them why. Then, we excluded respondents who answered: “I did not understand the different scenario”, “There were too many elements to consider”, “It is not my responsibility to pay”, or “I need more information to make up my mind”. Finally, our final sample comprises 483 inhabitants.

6.2 The Random Parameter Logit

Table 2: The Random Parameter Logit with Interactions.

	(1)		(2)		(3)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Mean						
Pay €	-0.19***		-0.19***		-0.19***	
	(0.02)		(0.02)		(0.03)	
SQ	-2.41***	3.22***	-2.38***	3.35***	-2.22***	3.18***
	(0.40)	(0.37)	(0.39)	(0.35)	(0.41)	(0.42)
AirTemp	0.59***	0.81***	0.36***	0.59***	-0.28*	0.70***
	(0.11)	(0.09)	(0.10)	(0.08)	(0.16)	(0.11)
Biodiversity	0.12***	0.14***	0.10***	0.13***	0.02	0.13***
	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)
NoTraffic-Low	0.04	-0.12	0.06	-0.53**	0.08	-0.30
	(0.14)	(0.81)	(0.15)	(0.23)	(0.15)	(0.35)
NoTraffic-High	-0.61**	1.61***	-0.80***	1.54***	-1.75***	1.47***
	(0.26)	(0.24)	(0.27)	(0.21)	(0.46)	(0.37)
Bio×AirTemp			0.90***	1.17***	0.87***	1.04***
			(0.21)	(0.17)	(0.16)	(0.14)
Bio×Biodiversity			0.08***	-0.06*	0.07**	-0.07**
			(0.02)	(0.04)	(0.03)	(0.03)
Bio×NoTraffic-High			0.71**	0.42	0.58**	0.49
			(0.30)	(0.41)	(0.28)	(0.40)
TramVege×AirTemp					0.75***	(0.11)
					(0.19)	(0.43)
TramVege×Biodiv					0.08***	(-0.03)
					(0.03)	(0.03)
TramVege×NoTraffic-High					1.15***	(0.51)
					(0.39)	(0.49)
Observations	8640		8640		8640	
N_clust	480.00		480.00		480.00	
ll	-2125.79		-2085.90		-2067.28	
aic	4273.59		4205.80		4180.56	
bic	4351.29		4325.89		4343.04	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results of the RPL are displayed in Table 2. As shown in the upper part of Table 2, all the coefficients associated with the chosen attributes are statistically significant - except for "NoTraffic - Low" as explained below - and have consistent signs. The coefficient "Pay €" is strongly significant and has a negative sign. As expected, respondents' utility decreases as the monthly local taxes increase, all else being equal. The coefficient "SQ" refers to the alternative specific constant (ASC). This latter represents the utility associated with being in the current situation (*i.e.*, no greening, no improved ecosystem services and no reduction of traffic and parking available space) as opposed to the hypothetical scenarios of tram greening. The negative sign and high significance of the ASC show that, on average, respondents are in favor of greening the tram compared to staying in the SQ situation. The positive signs and strong significance of the coefficients representing “AirTemp” and “Biodiversity” indicate that, on average, respondents have a strong preference for the impact of greening on reducing the temperature during hot periods and improving urban biodiversity, respectively. Note that the standard deviations of the mentioned coefficients are all highly significant, demonstrating a strong heterogeneity in preferences regarding these attributes. In other words, respondents are, on average, in favor of urban greening. They have a strong preference for the impact of greening on reducing the temperature during hot periods and improving urban biodiversity. However, not all respondents are of the same opinion (some may be against it, others are indifferent, and others are strongly in favor).

Coefficients “NoTraffic - Low” and "NoTraffic - High” respectively indicate how respondents’ utility varies when the space available for traffic and parking is, respectively, weakly or strongly reduced. The statistical insignificance of “NoTraffic - Low” shows that people are, on average, indifferent to such a low reduction, with relatively homogeneous preferences (insignificant standard deviation). The negative sign and statistical significance of “NoTraffic - High” shows that people are, on average, against a high reduction of the available space to circulate and park, although some are in favour and other against (very heterogeneous preferences as shown by the strongly significant standard deviation).

In the lower part of Table 2, we examine the interactions between our attributes and several socioeconomic and attitudinal variables. This allows us to understand how the respondent’s profile explains their preferences regarding the various attributes. The following variables were considered and only the significant interactions are depicted in Table 2: age, gender, level of education, revenues, number of children in the household, whether the respondent uses a car as main transport, uses a bike as main transport, regularly consumes organic products (variable Bio), is involved in pro-environment activities, ever uses the tram, ever uses public transports, thinks there is not much vegetation around the tram (variable “TramVege”), lives inside or outside the city of *Lyon* and the distance from the respondent’s residence to the closest tram station.

As shown in Table 2 (two last columns), we find that respondents who regularly consume organic products (which is a proxy for environmental sensitiveness) - and/or who believe there is not much vegetation around the tram - are more in favour of regulating high temperature through vegetation (they might be more aware of the climate change issue). They are also more sensitive to biodiversity improvements and accept more easily, than the average, a high reduction of space dedicated to parking and traffic.

We then compute the WTP/WTA associated with our attributes using a WTP-space model as shown in Table 3. According to our results, the interviewed population is, on average, willing to pay 3.82€ per month for each reduced degree in air temperature during heat waves. It is also willing to pay 0.77€ per month for increasing by 1% in the abundance of local birds, which indicates the state of the urban biodiversity. Last, respondents need to receive, on average, the equivalent of 2.38€ per month through reduced local taxes to accept a strong decrease in the space available for traffic and parking[7]. Once again, as for the estimated coefficients, we observe a strong heterogeneity among respondents regarding these WTP/WTAs, as shown by the strongly significant standard deviations.

Table 3: RPL in WTP space estimation.

	Mean	S.D.
SQ	-4.19	
	(2.88)	
AirTemp	3.82***	5.76***
	(1.34)	(1.34)
Biodiversity	0.77***	1.04***
	(0.30)	(0.22)
NoTraffic-Low	1.25	4.59**
	(1.18)	(1.99)
NoTraffic-High	-2.38*	11.38***
	(1.38)	(1.85)
Observations	8640	
N_clust		
ll	-2211.77	
aic	4445.54	
bic	4523.24	

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Given the strong heterogeneity in preferences shown in the RPL in preference and WTP Space models, it is useful to further examine the different profiles, or classes, of respondents. We, therefore, complete our estimations with a LCM.

[7]We do not interpret here the WTPs/WTAs that are not statistically significant as they are considered equal to zero.

6.3 The Latent Class Model

As described in section 5, the LCM allocates respondents to different classes, allowing specific coefficients' estimates for each class. It, then, describes the classes by informing how the socioeconomic characteristics of a respondent affect their probability to pertain to a given class.

Table 4: Information criteria and model selection

	Number of classes					
	2 classes	3 classes	4 classes	5 classes	6 classes	7 classes
AIC	4518.34	4333.56	4229.45	4168.79	4115.37	4075.38
BIC	4610.18	4467.78	4413.11	4401.91	4383.80	4372.07
Predictive quality (%)	97%	74%	37%	33%	32%	31%

As shown in Table 4, we have run several tests in order to determine the optimal number of classes in the LCM. According to the criteria of the predictive quality of the model[8], the optimal number of classes is 2.

Results for the LCM with two classes are shown in Table 5. As displayed in the upper part of Table 5, respondents in Class 2 are in favor of tram greening (negative and strongly significant coefficient associated to the SQ situation), whereas respondents in Class 1 are in average indecisive to move to greening alternatives (insignificant SQ coefficient). Both classes strongly dislike tax increases as shown by strongly significant negative coefficients for "Pay €" in both classes, as is consistent with intuition. While both classes appreciate a reduction in air temperature during hot periods and an improved biodiversity, we can notice that Class 2 is clearly more sensitive on these points with more significant and higher coefficients. Both classes are indifferent to low reductions of the space available for traffic and parking but, while Class 2 remains indifferent when the reduction becomes strong, respondents in Class 1 become strongly opposed to this reduction (high and strongly significant coefficient for "NoTraffic - High" in Class 1).

[8]Predictive quality measures the proportion of individuals who do belong to the class assigned to them based on their observed choices Nylund *et al.* (2007).

Table 5: Latent class model results

		Class 1	Class 2
		Coefficient	Coefficient
		(S.E.)	(S.E.)
Attributes			
	SQ	0.025	-1.47***
		(0.44)	(0.28)
	Pay €	-0.28***	-0.077***
		(0.05)	(0.02)
	AirTemp	0.26**	0.53***
		(0.11)	(0.09)
	Biodiversity	0.02	0.07***
		(0.01)	(0.01)
	NoTraffic - Low	0.03	0.14
		(0.27)	(0.15)
	NoTraffic -High	-1.49***	0.29
		(0.36)	(0.26)
Membership			
	Car	0.65**	Ref.
		(0.27)	
	EnvInvolv	-1.06***	Ref.
		(0.37)	
	Children	-0.33***	Ref.
		(0.11)	
	City center	0.55**	Ref.
		(0.26)	
	Gender	0.23	Ref.
		(0.26)	
	Income	0.11**	Ref.
		(0.07)	
	Age	0.00	Ref.
		(0.00)	
	Education	0.01	Ref.
		(0.10)	
N (obs.)		8640	
Log Likelihood		-2231.77	
AIC		4505.55	
BIC		4653.90	
Preditive quality		97%	
Class membership		23.9%	76.1%
Note:		*p<0.1; **p<0.05; ***p<0.01	

In sum, we seem to observe a pro-greening class including 76.1% of respondents (Class 2), which is very sensitive to climate regulation and biodiversity preservation, and easily accepts reductions in spaces allocated to car circulation and parking. The other class (Class 1), including 23.9% of the interviewees, seems globally indifferent regarding greening strategies and is open to fresher summers and improved biodiversity but not as much as Class 1. Moreover, this class is strongly concerned about the traffic and parking consequences of reducing the available space due to greening policies.

The lower part of Table 5 allows us to better understand who belongs to each class. The obtained results show that respondents using a car as main transport are more likely to pertain to Class 1 (positive and significant membership coefficient associated to "Car"). To a lower extent, respondents living inside the city of *Lyon* ("City center") and/or having a larger income ("Income") are also more likely to pertain to Class 1. On the other hand, respondents who have more children and/or who are involved in activities in favour of the environment (donations, voluntary work) are more likely to fit in Class 2, as shown by the negative signs of the membership coefficients "Children" and "EnvInvolv". This environmental involvement, as the fact of consuming organic products, is a proxy for the respondent's environmental sensitiveness[9].

7 Conclusion

Extreme heat events and floods are becoming more frequent in most cities worldwide, in the context of climate change. Cities are forced to accommodate a growing population in an increasingly polluted and artificialized environment. The summer of 2022 was also marked in France by heat waves and forest fires. It had been 16 years since the fires had been so destructive in France.

These recent heat waves and the associated damage have led the French government to take short-term measures. On June 14, 2022, the government announced the creation of a fund of 500 million euros for the "renaturation" of cities, which are the places where the heat is the most significant. The government aims to promote the development of islands of freshness in the city by making a very strong commitment to supporting local communities in adapting to the consequences of climate change.

One of the means that cities have to bring nature into the city is through the greening of transport infrastructures. The metropolis of *Lyon*, subject to recurrent heat waves, has taken actions in this direction for several years by increasing the vegetation of the city (e.g., the number of trees, the number of urban parks) and by investing in public transport infrastructure, in particular by extending the tram network.

[9] The same model replacing "EnvInvolv" by "Bio" has been run and yields very similar results.

While green tram network brings urban ecosystem services, such as cooling of air temperature, increase in bird abundance, it also reduces the space available for vehicle traffic and parking. This paper measured the WTP of the inhabitants of *Lyon* for the vegetalization of the tram network with a Discrete Choice Experiment (DCE) valuation method, conducted in 2022. Apart from the estimation of the average WTP, we also analyzed the determinants of individual heterogeneity in WTP.

Using a sample of 500 respondents, we show that on average, respondents are in favor of urban greening, having a strong preference for the impact of greening on reducing the temperature during hot periods and improving urban biodiversity, respectively. However, a negative parameter in the model obtained from this study suggests that respondents are, on average, against a high reduction of the available space to circulate and park for the development of green areas. Results also demonstrate a high heterogeneity in inhabitants' preferences partly driven by their sensitivity and commitment to the environment.

Our empirical results suggest that if there was a referendum in the considered region to decide whether to implement a greening program of the tram, the majority would be in favor. However, we must keep in mind that a significant portion of the population is worried about the space implications of such a program. To improve its popularity, finding a compromise with greening that does not encroach too much on the city space - such as vertical vegetation - would be most welcome. This analysis thus helps to understand the potential reluctance of inhabitants and the social acceptability of green tram network in *Lyon*, contributing in fine to guide the design of local public policies.

Author Contributions

For this article B.B., C.C.-V. and M.D. did the ground exploration and the initial research to acquire the theoretical framework. M.D. focused on the discrete choice experiment. All authors contributed to the selection of the attributes and the conception of the case study. The data was collected by a survey agency. L.T. made the literature review on UGS and UES. L.T., S.A., and M.D. realized the statistical analyses. All authors have read and agreed to the present version of the manuscript.

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