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BEYOND SURVEYS: USING IMMERSIVE VIRTUAL REALITY TO EXPLORE SUSTAINABILITY PREFERENCES

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Beyond Surveys: Using Immersive Virtual Reality to Explore Sustainability Preferences

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Abstract

The present work examines urban residents' preferences for biodiversity conservation, heatwave-related living conditions, and traffic-related noise and pollution, using a discrete choice experiment (DCE), also considering willingness-to-pay (WTP) and the influence of immersive virtual reality (VR) exposure, focusing on the metropolitan area of Athens. More importantly, VR exposure examined whether individuals' preferences were affected, focusing on its methodological contribution to the better planning of urban sustainability interventions. According to the results, biodiversity emerges as the most valued attribute, followed by heatwave measures, and then, traffic reduction, and VR exposure affects individuals' preferences for traffic measures, emphasizing its methodological value for improving urban sustainability decisions.

Keywords: Discrete choice experiment; Urban sustainability; Biodiversity protection; Heatwave mitigation; Traffic pollution; Virtual reality; Environmental preferences

Introduction

Sustainability has gained interest from stakeholders, policymakers, and scholars, as it provides avenues for more resilient ways to render habitats, especially urban ones, livable. The use of Virtual Reality (VR) in Discrete Choice Experiments (DCEs) can improve realism and cognitive engagement compared to traditional survey formats. Classical methods rely on textual or static visual descriptions, which may lead to abstraction bias when valuing complex environmental goods, as respondents' understanding affects preference reliability (Louviere et al., 200). VR addresses this challenge by immersing individuals in simulated environments where complex attributes coexist in various level combinations, improving experience, reducing bias, and enhancing understanding.

The literature argues on the importance of decision and perceived realism in stated preference settings (Bateman et al., 2002). VR can help cognitive and emotional engagement (Vassilopoulos et al., 2023), which are important for non-market goods, with empirical evidence showing that better visualizations influence willingness to pay by clarifying scope and magnitude effects (Guilfoos et al., 2023). Thus, VR-based DCEs contribute methodologically.

With increasing global warming, dense urban regions face degradation, so blue-green spaces are considered necessary for urban heat (Jiang et al., 2025), thus, environmental resource use is important to reduce degradation (Zekri et al., 2025). Heatwaves, which have become more frequent, longer, and more intense, especially in areas with limited green space (Tian et al., 2025), are a challenge for urban sustainability, as more than half of urban residents face strong or extreme heat stress due to urbanisation and climate vulnerability (Adeyeri et al., 2025). Such high temperatures relate to mortality, reduced productivity, energy shortages, and increased socio-economic inequalities, especially among vulnerable groups (Akatah et al., 2025).

Transportation sustainability is necessary for a more sustainable environment, as it contributes to environmental degradation, particularly in rural areas where transitions depend on institutional trust, social mobilization, and policy stability (Tsai and Chen, 2026), alongside incentives linked to sustainable mobility and tourism (Daglis, 2023).

The sustainable pathway requires synergy among green spaces, biodiversity protection, sustainable transportation, pollution reduction, and climate stabilization. Green spaces help lower air pollution and improve acoustic conditions, enhancing human well-being (Rey-Gozalo Guillermo, 2025). Cities must adopt integrated strategies that address environmental and human needs and prioritize green infrastructure.

DCEs are an important tool for quantifying preferences for sustainable choices (Koundouri et al., 2012), especially in the environmental domain (Remoundou et al., 2015; Birol and Koundouri, 2005, 2008; Koundouri, 2009). This study uses DCE to examine how people value biodiversity, transportation, and living conditions (mainly due to heatwaves), while testing the effect of VR on their choices.

The remainder of this work is structured as follows: literature review, methodology, data and results, and conclusions.

Survey & Methods

In this section, we first present the VR and the survey that were designed, and we then present the methods followed. This work aims to examine the preference of people regarding biodiversity protection, the alleviation of traffic externalities associated with noise and pollution, the living and working conditions, and the effect of a VR environment on individuals' choices. The case study focuses on the metropolitan area of Athens, a region that faces such challenges.

VR environment

The VR application was developed in the Unity engine as an immersive environment, compatible with Meta Quest Oculus 2.0 and 3.0 devices. Following Halkos et al. (2024), we identified the main challenges related to these hazards and the associated costs for participants. The attributes were defined across three levels: (i) status quo, where conditions worsen if no willingness to pay is expressed; (ii) medium status, where some measures stop further deterioration; and (iii) good status, achieved through extensive measures.

The VR environment incorporated these features based on the same procedure used for the DCE. Attribute visualization relied on relevant environmental features without explanatory text, aiming to minimize differences between the printed and VR versions and allow experimental comparison.

The virtual environment represents a city square where attribute combinations form alternative futures. For example, the "Heatwaves: Bad" level shows people suffering from heat and arguing, while the "good" level shows people comfortably resting in shaded areas. Similarly, for the Flora and Fauna attribute, the "bad" level includes sick or dead animals and trees, while the "good" level shows them in healthy condition. These alternative representations are illustrated in Pictures 1–5. The combinations of attributes are presented in 8 choice cards, following the classical DCE design, with attributes detailed in Table 1 of the Appendix.



Picture 1. Good status of biodiversity loss prevention



Picture 2. Bad status biodiversity loss



Picture 3. Good status biodiversity loss, and good status of heatwaves.



Picture 4 Deteriorating conditions of transportation



Picture 5. Good status of transportation

Classical DCE-Survey

The abovementioned attributes and levels are also the same for the online survey. The costs are 0€ for the case the respondent does not want to pay, 30€ for choice A, and 100€ for choice B, representing the annual household cost. We provide this information in Figure 1.

The survey first starts by asking the respondents about their willingness to participate, then some basic personal information, and their opinion regarding the Athens Metropolitan Area and the responsible agents. Then continues with the Choice cards, eight in total, then follows the demographic questions, and finally, the respondents' opinion on the survey and its difficulty to fill. Table 1 depicts the questions of the survey.

Question
Happy to Participate
In what city and country were you born
In what city and country do you currently live
Is there anything in the urban environment that you perceive as being important to your culture
It is absolutely safe to say that the Athens Metropolitan Area is currently experiencing environmental damage degradation due to human activities
The quality of life in the Athens Metropolitan Area needs to be improved
Improving the quality of life of the Athens Metropolitan Area is the responsibility of The Government
Improving the quality of life of the Athens Metropolitan Area is the responsibility of Local Regional Authorities
Improving the quality of life of the Athens Metropolitan Area is the responsibility of Everyday Citizens
A high level of quality of life is essential for tourism development

Taxes are a more stable way of maintaining the funding necessary to successfully manage the urban environment than are donations and EU funds

We should do something to significantly reduce air pollution in Athens Metropolitan Area even if the economy slows down because of this

Choice card 1

Choice card 2

Choice card 3

Choice card 4

Choice card 5

Choice card 6

Choice card 7

Choice card 8

What is your gender

What is your age

Please describe your marital status

Do you have children and or grandchildren under the age of 18

Educational level having been completed

Occupation

Is your work focused on the environment?

Please provide us with the total annual income after taxes earned by all members of your household last year

Are you currently a member of an environmental organization?

Please write the names of the organizations

Please provide us with the reasons for your participation in the survey

How easy or difficult was the choice tasks How easy or difficult was the choice task in Part I

How easy or difficult was the choice tasks How easy or difficult was the choice task in Part

III

How easy or difficult was the choice tasks How easy or difficult was the choice task in Part

IV

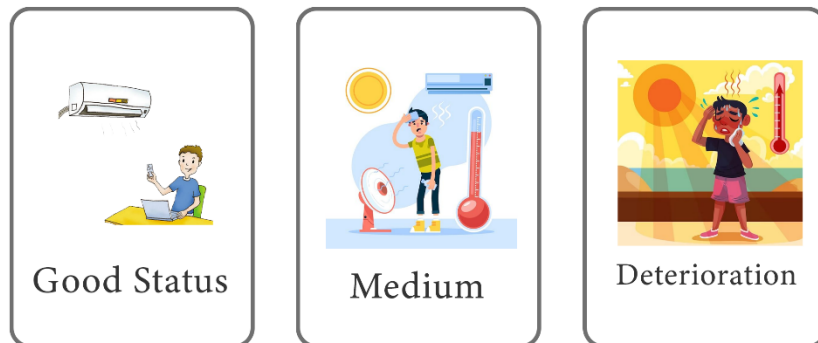
Biodiversity loss



Traffic



Living and Working Conditions to Heatwaves



Annual Household Cost

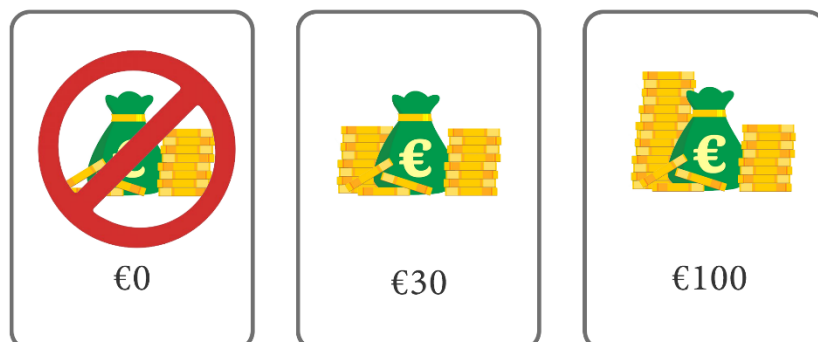


Figure 1. Illustration of the levels for each attribute.

We employ the conditional logit model, which is often used in the context of DCEs (Liu et al., 2018; Ros, 2023), and is a popular approach due to its robustness and simplicity, as well. We follow the notation of Liu et al. (2018). Specifically, let x_{ijk} the attributes in a vector form, for the j-alternative in the k-question that each respondent-i is asked to answer. Then, a linear random utility model is defined as:

$$u_{ijk} = x'_{ijk}\beta + \varepsilon_{ijk} \quad (1)$$

where ε_{ijk} are the errors.

Assuming that the errors are individual idiosyncratic preferences, distributed independently and identically, under the distribution of type I extreme values, then, the probability for the i-individual to select the j-alternative among the alternatives in k-question can be written as:

$$Prob(Y_{ik} = j) = \frac{\exp\{x'_{ijk}\beta\}}{\sum \exp\{x'_{ink}\beta\}} \quad (2)$$

Since individual-level choices are observed for each question, we may construct the likelihood function using these probabilities, and then maximize this function with respect to β to obtain estimates of the attribute-specific utility parameters, with standard errors clustered at the individual level.

Results

In this section, we first present the data, and then we analyze the results obtained. As a first stage of our analysis, during the tests, we identified that none of the VR respondents chose the status quo, by not paying any amount. On the other hand, only 2.5% of the online survey chose the status quo in any case (none from the VR), which represents a “protest” response, based on their responses on the debriefing section (Barrio and Loureiro, 2013). Therefore, these answers were excluded from the analysis, and the status quo option (0€) was excluded from the analysis. Therefore, this gives even more credit to the econometric method selected for the analysis of our research. The final sample size was 68 for the online survey and 99 for the VR. The frequency of the individuals’ choices is reported in Table 2.

Table 2. Frequency of the individuals’ choices.

Choice card No	People selecting 30 euros	People selecting 100 euros
Choice card 1	114	53
Choice card 2	89	78
Choice card 3	109	58
Choice card 4	66	101
Choice card 5	92	75
Choice card 6	147	20
Choice card 7	17	150
Choice card 8	102	65

We then provide the model results in table format (Table 3), and we illustrate (Figure 2) the estimated utilities.

Table 3. Model results.

Variable	Coefficient t	Exp (coefficient)	Standard Error	Z-stat	P-value
Biodiversity loss (Good Status)	2.221	9.219	0.396	5.616	<0.001
Biodiversity loss (Moderate)	1.802	6.061	0.224	8.042	<0.001
Traffic (Good Status)	0.590	1.804	0.284	2.076	0.038
Traffic (Moderate)	0.764	2.147	0.172	4.447	<0.001
Working and Living Conditions (Good Status)	1.042	2.835	0.321	3.241	0.001
Working and Living Conditions (Moderate)	1.482	4.401	0.220	6.751	<0.001
Annual Household Cost	0.000	1.000	0.002	-0.233	0.816
Biodiversity loss (Good Status): VR	0.836	2.308	0.824	1.015	0.310
Biodiversity loss (Moderate): VR	0.376	1.456	0.428	0.878	0.380
Traffic (Good Status): VR	3.073	21.613	0.748	4.107	<0.001
Traffic (Moderate): VR	1.297	3.659	0.394	3.289	0.001
Working and Living Conditions (Good Status): VR	1.006	2.735	0.780	1.290	0.197
Working and Living Conditions (Moderate): VR	-0.428	0.652	0.424	-1.009	0.313
Annual Household Cost: VR	-0.003	0.997	0.003	-1.126	0.260

* Model diagnostics: Concordance= 0.73 (se = 0.017), Likelihood ratio test= 467.3 (p-value<0.0001), Wald test= 248.6 (p-value<0.0001), Score (logrank) test = 398.3 (p-value<0.0001)

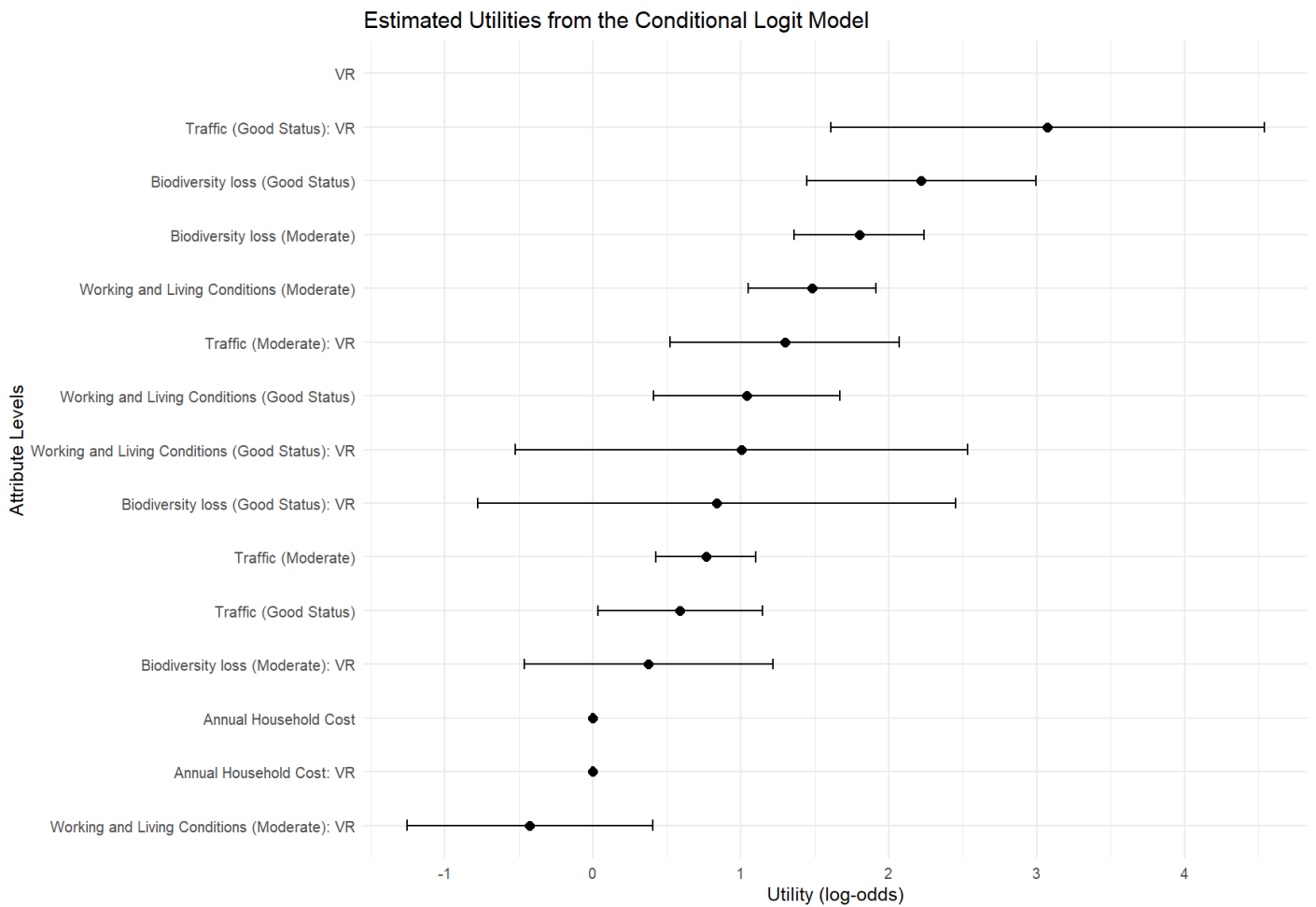


Figure 2. Utilities for the conditional logit model.

According to the results, the VR environment significantly amplifies preferences for traffic improvements, indicating that respondents exposed to VR are more sensitive to changes in

noise and pollution, while VR does not significantly affect biodiversity, living and working conditions (related to heatwaves), or cost.

Moreover, the respondents mainly prefer improvements in environmental and working conditions, with the largest utilities observed for biodiversity loss prevention (Good: OR = 7.49, and Moderate: OR = 4.62), followed by living and working conditions related to heatwaves (Good: OR = 3.21, and Moderate: OR = 4.09), and then follow traffic-related noise and pollution (Good: OR = 1.78, and Moderate: OR = 2.15). Moreover, the annual household cost does not appear to significantly influence choices.

The model's performance can be regarded as very good, citing a concordance score of 0.716, with all tests being highly significant ($p < 0.001$), demonstrating that the attribute levels jointly explain choices very well and that the model predicts respondents' choices accurately.

Conclusion

This study employs a discrete choice experiment, contributing to the literature on environmental preferences by providing a multidimensional framework across three major sustainability domains: biodiversity, climate change, heatwave-related conditions, and traffic externalities. It also tests whether the means of implementation play a role, specifically comparing a survey and a VR experiment. Hence, this work extends the existing literature by offering new evidence on the multidimensional nature of urban sustainability preferences for the metropolitan area of Athens.

A key aspect is the use of Virtual Reality (VR), testing whether this immersive environment influences environmental preferences. While the literature acknowledges the significance of information interventions (Jiang et al., 2023) and behavioral aspects, few studies examine the effect of VR in DCEs. The results provide support for such approaches, showing that VR strengthens preferences for improvements in traffic-related aspects with strong statistical significance; however, its effect on biodiversity and heatwave-related conditions is not statistically significant. A possible explanation is that traffic-related aspects (e.g., noise, pollution, street-level disturbances) are highly perceptual, with intense stimuli, and VR exposure amplifies awareness, whereas biodiversity and heatwaves involve broader benefits less effectively communicated through immersion. These findings highlight the importance of matching audio-visual technologies with the type of environmental goods evaluated.

Several policy implications emerge, particularly for integrated urban sustainability strategies combining ecosystem protection, climate adaptation, and mobility reforms. Policymakers should note that residents value biodiversity most, followed by heat mitigation, supporting investments in nature-based solutions, urban greening, shading infrastructure, and climate-resilient design. VR-enhanced planning may also improve communication of traffic-related externalities and increase public support for low-emission zones and noise reduction measures.

Finally, the non-statistical significance of annual household costs suggests limited sensitivity to monetary aspects or dominance of environmental gains over economic trade-offs. In high-tax contexts, such as Greece, budget constraints may reduce overall willingness to pay, although marginal WTP remains significant. This aligns with findings where environmental goods are perceived as essential or public-good oriented (Haron et al., 2025; Notaro et al.,

2025). Future research could test similar designs in lower-tax contexts and explore richer multisensory VR features, such as dynamic heatwave visualizations or ecological simulations, to further assess the effectiveness of immersive technologies in environmental valuation.

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Appendix


Three attributes were selected for visualization within the Virtual Environments: (1) *Biodiversity Loss*, (2) *Quality of Life*, and (3) *Heatwaves*. Each attribute is categorized into three status levels: poor, moderate, and good. Specifically, Biodiversity Loss encompasses the state and quantity of flora and fauna. Quality of Life accounts for traffic, noise, air pollution, and commercial and residential conditions. Finally, Heatwaves describe the impact on indoor and outdoor jobs, as well as the general well-being of citizens.

In Table 1 we present the design approach for the visualization of Biodiversity Loss in the virtual environments.

Table 1. The visual design approach of the three levels of the Biodiversity Loss attribute

Biodiversity Loss	Scenes	Fauna	Flora	Picture
Bad	A few animals and plants. All are in bad condition.	Sparrows (1 Flying - 1 Idle) Pigeons (1 Idle - 2 Moving) Swallows (3 Dead - 1 Idle) Robins (1 Dying) Dogs (1 Tired)	Oleander (6), Lombardy Poplar (4), Broadleaf (11)	

<p>Moderate</p>	<p>Most animals and trees are in good condition. More animals and plants than in the Bad condition.</p>	<p>Sparrows (1 Flying - 3 Idle)</p> <p>Pigeons (2 Idle - 3 Moving)</p> <p>Swallows (3 Idle +Nest - 3 Flying)</p> <p>Robins (4 Moving - 1 Idle)</p> <p>Dogs (1 Walking - 1 Idle)</p> <p>Cats (1 Sleeping - 1 Idle - 1 walking)</p> <p>Worms (2 near pigeons)</p>	<p>Oleander (13), Cypress (3), Olive Trees (3), Lombardy Poplar (3), Broadleaf (11)</p>	
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<p>Good</p>	<p>A great variety of plants and animals are in good condition.</p>	<p>Sparrows (2 Flying - 3 Idle) Pigeons (3 Idle - 4 Moving) Swallows (3 Idle +Nest - 3 Flying) Robins (4 Moving - 1 Idle) Dogs (1 Walking - 1 Idle - 1 puppy) Cats (1 Sleeping - 1 Idle - 1 walking) Worms (2 near pigeons) Owl (1 Flying) Geckos (3 Idle) Flock of Birds (5 birds in the sky) Ants (a line) Bees (over 1 bush) Blue Jays (2 Idle)</p>	<p>Oleander (13), Palm Trees (2), Weeping Willows (2), Cypress (5), Lombardy Poplar (7), Olive Tree (3), Broadleaf (14)</p>	
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