The Role of Environmental Awareness in Transport Mobility Behaviour: Evidence from Survey-Based Approach in Catania (Italy)

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Abstract. According to the European Environment Agency (EEA) estimates, road transport represents one of the main contributors to greenhouse gas emissions in Europe. Reducing its environmental impact is a key challenge in achieving sustainable mobility systems. While policies are increasingly oriented toward low-carbon fuels, zero-emission technologies, and modal shifts to public transport, recent research has highlighted the growing importance of users' perceptions and attitudes in influencing mobility behaviors. Environmental awareness has emerged as a key factor in shaping transport choices. Based on this premise, this study investigates the role of environmental awareness in the transport mode choices of citizens in Catania (Italy), a context characterized by high motorization rates and traffic congestion. Based on a structured questionnaire administered to a sample of 1,373 respondents via both CAWI (Computer-Assisted Web Interviewing) and CATI (Computer-Assisted Telephone Interviewing) techniques, the analysis explores the association between environmental awareness and variables such as frequency of public transport use, gender, age, and occupational status. Respondents' awareness was assessed with reference to air quality, traffic congestion, and noise pollution through a 5-point Likert scale. Descriptive and non-parametric statistical analyses (i.e. Mann–Whitney U test, Kruskal–Wallis and Dunn's post-hoc) were applied to examine correlations between awareness and socio-demographic variables, as well as travel behaviour. Effect size was also computed to assess the practical relevance of the results. The findings provide valuable insights for designing more targeted and effective sustainable mobility policies, especially in contexts with high car dependency. Further research will examine how the willingness to adopt alternative transport varies according to personal motivation and perceived convenience.

Keywords: Public perception · Environmental externalities · Sustainable transport · Demand Responsive Transit (DRT) · Urban mobility

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1 Introduction

The notion of '*sustainable development'* [1] combines the requirements of economic growth with those of human and social development, quality of life and protection of the planet from a long-term welfare perspective.

Since the concept of "*sustainable development*" was enunciated, numerous initiatives, protocols and regulations have been established for its implementation, across the different aspects involving the life of the community. Over the past decades, moreover, the emergence of climate change is becoming increasingly pressing, and adaptation and mitigation measures are becoming necessary to prevent the related problems that are already ongoing (floods, urban heat islands, loss of biodiversity, air pollution, increase in greenhouse gases, etc.).

The United Nations (UN) has developed 17 Sustainable Development Goals (SDGs) in the 2030 Agenda [2], among which Goal 11"*Sustainable Cities and Communities*" aims to "*make cities and human settlements inclusive, safe, resilient and sustainable"*. Among the different targets it aims to promote a participatory and integrated transport-land planning; to reduce the environmental impact of the cities; to ensure access to safe and economic living spaces and transport systems.

The European strategy [3] has as its aim to make the European Union (EU) economy sustainable through a set of initiatives geared toward making the economy achieve climate neutrality Union by 2050. The Green Deal is the EU's new growth strategy that aims to transform the EU into a modern, efficient and competitive economy, with the goal of zero net greenhouse gas emissions by 2050. It also intends to protect, conserve and enhance the EU's natural capital and protect the health and well-being of citizens from environmental hazards and their consequences. The Green Deal intends, therefore, to guide the EU toward a socially just transition and a sustainable economic system so that no person and no place is excluded. It will contribute to the goal of creating an economy that serves citizens by strengthening the EU's social market economy, generating stability, jobs, growth, and sustainable investment [3]. The principal actions are the efficient use of resources through the transition to a clean, circular economy, the curbing of biodiversity loss, the reduction of pollution, sustainable transport and actions against climate change.

Cities play a key role in combating climate change and implementing actions aimed at reducing greenhouse gases, especially through sustainable transportation planning. Promoting sustainable transport is crucial to reducing greenhouse gas emissions and improving public health. Measures such as increasing bicycle lanes, enhancing public transportation, and adopting electric vehicles can reduce pollution and encourage a more active lifestyle.

Programs such as the Recovery and Resilience Plan (RRP) and the European Green New Deal aim to integrate sustainability into urban policies, promoting a circular economy and greater social cohesion.

The transport sector is one of the largest sources of greenhouse gas emissions in the EU. Since 2005, however, transport emissions have not decreased significantly, despite the implementation of some measures aimed at reducing them (such as increasing the diffusion of electric vehicles). The EU expects domestic transport emissions to decrease below 1990 levels only in 2032 and, among the various transport modes, emissions from

international aviation and maritime transport will continue to increase. The reduction of emissions is one of the biggest challenges for achieving the sustainable transformation of EU mobility systems [4]. The analysis of domestic greenhouse gas emissions in the EU transport sector shows a weak downward trend since 2005. Obviously, the most significant decrease occurred in 2020 because of the Covid-19 pandemic. Since 2021, as expected, emissions have recovered, although showing a weak decline of 0.8% in 2023 (Fig. 1). Based on European data projections, Member States expect transport emissions to decrease overall in the coming decades. This scenario is projected based on both emission reductions due to current policies and measures and additional reductions that the planned measures may generate (Fig. 2).

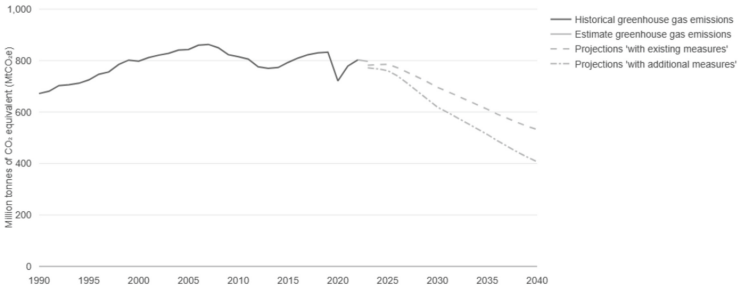

Fig. 1. Historical, estimate and projections greenhouse gas evolution [4].

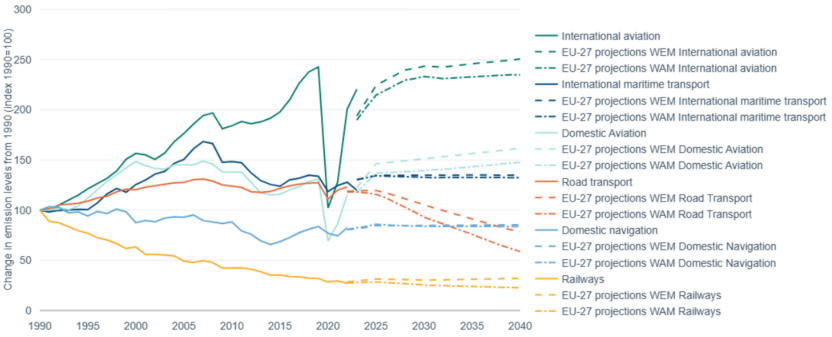

Fig. 2. Trends in greenhouse gas emissions by transport type and their projections [4]

Greenhouse gas emissions from transport are projected to be 4% higher than 1990 levels by 2030 with current policies and measures. In contrast, if additional measures are taken, these emissions would be 8% below 1990 levels. Most of the planned policies and measures in the transport sector involve promoting low-carbon fuels or zero-emission technologies, as well as encouraging modal shift to public transport [4].

According to EEA estimates, by 2022, the mode of transportation with the greatest impact on greenhouse gas emissions is road transportation (71.7%), in which cars account for 60.6% and heavy-duty trucks for 27.1%, followed by water navigation (14.0%) and civil aviation (13.4%) (Fig. 3).

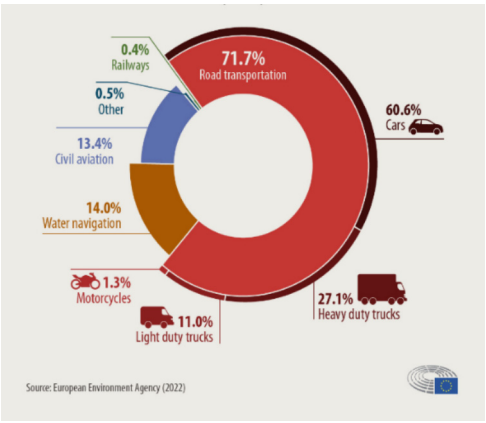

Fig. 3. Transport greenhouse emissions in the EU breakdown by transport mode (2022)

In Italy, the transport sector is directly responsible for 25.2% of greenhouse gas emissions and 30.7% of CO2 emissions, in addition to emissions from international aviation and maritime transport. 92.6% of national emissions in the entire sector are attributable to road passenger and freight transport, a sector for which there was a 3.2% increase in emissions between 1990 and 2019, in contrast to the 19% drop in total emissions during the same period. To help achieve the European objectives of the "Fit for 55" package, which envisage a 55% reduction in climate-changing emissions by 2030 and their zeroing by 2050, it is necessary to accelerate the decarbonisation process, starting with the mobility sector (Mims, 2022) [5].

In recent decades, economically advanced countries have activated various actions in order to reduce their level of emissions and, consequently, the environmental and social impacts caused on the lives of their citizens. Many of these impacts are concentrated on urban ecosystems, which, at present, represent about 3.0% of the earth's surface, but are responsible for 75.0% of carbon emissions due to human activities [6].

Considering the three dimensions of sustainable development, the externalities mainly considered associated with the transport sector are: air pollution (environmental), fuel consumption (economic), traffic congestion and road accidents (social) [7, 8]. The literature has shown in various research that the transport sector determines the generation of positive and negative externalities, which affect the quality of life, especially in urban areas [9–11].

Literature offers the results of numerous studies that have analysed the variables influencing the choice of mode of transport and intermodality (cost [12], distance, [13], comfort [13], time [14], connectivity [15]), but few studies examined the motivations linked to the aspects of environmental sustainability in the choice of mode of transport.

In recent years, the literature on urban transport has been enriched by applications analyzing perceptions and attitudes of transport users [16], which have examined the convenience of using certain modes [17], greater or lesser risk aversion or perceived safety [18], perceptions of the level of service [19]. Recently, increased attention has been paid to the study of environmental variables in the choice of modes of transport,

and environmental awareness has been identified as a significant variable in studies on the choice of mode of transport among the general population [7, 8, 20–23] or targeted user groups, such as university students [7, 8, 24, 25].

This work examines the role of environmental awareness on transport mode choice among the citizens of Catania (Italy), through a sample of 1,373 respondents, with the use of a structured questionnaire, carried out by telephone and online. Knowing the degree of awareness of environmental issues, in general, and those related to urban transport, in particular, are of fundamental importance for developing effective sustainable mobility actions, in a co-governance approach with citizenship in the transition towards a model of sustainable and resilient cities, especially in cities with high rates of motorisation and traffic congestion. The results presented are part of a more extended survey that was carried out with the general objective of assessing the propensity of users towards innovative shared transport systems (Demand Responsive Transit – DRT) and also the willingness to pay for the service [7, 8].

Section 2, after briefly illustrating the territorial framework, describes the survey data collection and the statistical methods; Sect. 3 reports the main results obtained and discussion, finally, Sect. 4 concludes the paper. The empirical analysis in this research focused on the degree of environmental awareness present among citizens, especially with reference to urban transport. The results could provide valuable insights for policymakers seeking to promote sustainable urban transport and improve the quality of life in urban areas, pursuing what is envisioned by SDG 11"*Sustainable Cities and Communities*" of the UN 2030 Agenda [2].

2 Materials and Methods

This section presents the analytical framework adopted for the study, starting with the description of the case study context. Then, it outlines the main aspects investigated through a structured survey, which served as the basis for data collection. Finally, the analysis statistical and methodological approaches applied for data processing and interpretation are described.

2.1 Territorial Framework

The selected case study coincides with the metropolitan city of Catania, located in the southeast coast of Sicily (Italy). Only the city of Catania has a territorial extension of 180,000 m^2 and a population of about 300,000 inhabitants [26].

The city of Catania is densely populated in its northern part, while the southern part (corresponding to the VI municipality) is mainly an industrial, airport and commercial area. However, it is necessary to highlight that some populous suburban neighborhoods administratively belong to neighboring municipalities as fractions. There are ten first-crown municipalities which, through urban sprawl processes, have been characterized by a strong increase in population to the detriment of the municipality of Catania, which has gone from over 400,000 residents in the early seventies to around 300,000 nowadays. The total population of these municipalities is about 400,000.

Catania is a city facing significant mobility challenges, primarily due to a functional imbalance in its urban structure, a scattered and disordered population distribution over a wide and heterogeneous territory, and the inefficiency of adequate transport systems. These critical issues contribute to a general decline in the quality of life for its residents, particularly in terms of health and well-being. According to the national *Quality of Life* ranking published by *Il Sole 24 Ore*, Catania ranks 83rd out of 107 Italian cities. Among the evaluated dimensions, the city shows its worst performance in the *urban ecosystem* index, which includes the assessment of urban transport, where it has dropped five positions compared to 2023 [27].

In such urban contexts, it becomes essential to foster environmental awareness among citizens. Raising consciousness about the negative impacts of traffic-related pollution, while simultaneously demonstrating that concrete and accessible actions can be taken to mitigate these effects, plays a crucial role. Encouraging individuals to recognize both the consequences of their mobility choices and the opportunities for more sustainable behaviors represents a necessary step towards improving urban livability and promoting collective responsibility.

To this end, the study proposes an analysis of a complex real-world context, focusing on the urban area of Catania and its surrounding municipalities. Particular attention is given to assessing users' environmental awareness through an extensive survey, as detailed in the following subsection.

2.2 Survey Data Collection

The data for this study were collected through a structured questionnaire, designed to assess the environmental awareness of users regarding mobility patterns. The questionnaire was distributed using both CAWI (Computer-Assisted Web Interviewing) and CATI (Computer-Assisted Telephone Interviewing) techniques, which were employed to maximize respondent diversity and reduce selection bias [7, 8]. The use of both methods allows for a more representative sample, as it reaches individuals with varying access to technology and communication preferences, thus enhancing the robustness and generalizability of the results.

The first section of the questionnaire focused on socio-demographic variables to create a comprehensive profile of the respondents. These variables included gender, age, level of education, employment status, income, household structure, presence of people with disabilities in the household, and residential location. The second section gathered information on transport-related variables, primarily addressing respondents' mobility patterns and access to various transport modes. Variables such as possession of a driving license, the number of household cars, motorcycles, bicycles, and e-scooters were examined. Additionally, the frequency of public transport use and possession of a public transport season ticket were also considered. In the third section, respondents were asked to evaluate statements related to environmental awareness. They were specifically asked to assess the impact of habitual car use and the potential change in mobility habits (i.e. replacing cars with public transport) could have an impact on air quality, traffic congestion, and noise pollution. To capture these judgments, a 5-point Likert scale was employed, ranging from "not at all" to "very much.", as it is a well-established tool

for measuring attitudes and perceptions on an ordinal scale. In this way, it is possible to effectively quantify subjective assessments, enabling reliable analysis for further descriptive and inferential statistics.

2.3 Statistical Methods

Following the data collection, a pre-processing phase was conducted to ensure the quality of the dataset. During this phase, incomplete interviews were excluded, and the response times were checked to ensure that only those interviews with reasonable completion times were considered, in line with the expected time necessary for respondents to answer thoughtfully. Once the data had been cleaned and organized into a final dataset, an initial descriptive statistical analysis was performed to examine the profile of the respondents and explore their mobility habits. This preliminary analysis served as the foundation for the subsequent correlation analyses.

Based on the judgments provided via the Likert scale, the respondents' environmental awareness was assessed in relation to air quality, traffic congestion, and noise pollution. Then, correlation analyses were conducted to investigate the relationship between environmental awareness and the following variables:

- frequency of public transport use, distinguishing non-users, occasional users, and frequent users;
- gender, i.e., male and female;
- age, divided into four groups, 18–25, 26–40, 41–55, and 56 and over;
- occupation, considering the following categories: Full-time/part-time employed, Self-employed, Unemployed, Housewife/Househusband, Student, and Retired.

To examine differences in environmental awareness across these categorical variables, non-parametric statistical methods were employed. Specifically, the Kruskal-Wallis test was employed, as it is suitable for comparing more than two independent groups when the dependent variable is measured on an ordinal scale. Following, Dunn's post-hoc test with Bonferroni adjustment was performed to identify which pairs of groups differed from each other. The Mann–Whitney U test was used as the non-parametric alternative to assess whether significant differences existed between two independent groups [28], as in the case of gender. Additionally, the effect size [28] was computed to quantify the magnitude of the observed differences, providing an indication of their practical relevance beyond statistical significance.

3 Results and Discussion

This section presents the main findings of the study. First, a descriptive statistical analysis is provided to outline the profile of the respondents and offer an overview of their mobility habits and socio-demographic characteristics. Then, the outcomes of the correlation analysis are discussed, with a focus on the relationship between respondents' environmental awareness and several categorical variables related to their socio-demographic status and transport behavior.

3.1 Descriptive Statistical Analysis

After conducting data cleaning and excluding inconsistent answers, a total of 1,373 valid responses were obtained. Table 1 provides a summary of the socio-economic and demographic characteristics of the sample. The survey was administered to a heterogeneous sample approximately evenly distributed between urban and suburban residents, living either within the city of Catania and within the surrounding municipalities. The composition of the sample was almost evenly balanced between male and female respondents. To ensure age diversity, participants were classified into four age groups; however, given the focus of the study on mobility habits and the willingness to adopt innovative transport alternatives, a slight predominance was observed among respondents aged 26–40 and 41–55.

The survey also investigated participants' level of education and employment status. Over 85% of the sample had achieved an education level of at least upper secondary school. In terms of occupation, more than 50% of respondents declared being employed, either full-time, part-time, or self-employed. Nevertheless, other categories such as students, unemployed individuals, housewives/househusbands and retirees were also meaningfully represented. From an economic standpoint, just over half of the respondents declared to have a lower-middle income, while approximately 30% identified themselves as earning an upper-middle income. The average household size was three to four members, with more than 10% of respondents reporting the presence of at least one person with a disability in their household.

Regarding transport-related variables (see Table 2), the data reveals a strong reliance on private vehicles, as more than 80% of the respondents reported owning one or two cars per household. Additionally, nearly half of the sample identified as non-users of public transport, further confirming a predominant preference for private mobility solutions.

3.2 Correlation Analysis

To investigate respondents' environmental awareness, they were asked to rate on a 5-point Likert scale from "not at all" to "very much" how much habitual car use and changing mobility habits by replacing cars with public transport could impact air quality, traffic congestion, and noise pollution. Table 3 shows the frequency distribution of the respondents' scores in percentile. Respondents' general perceptions reveal a clear awareness of the environmental impacts associated with habitual private car use. Among the assessed dimensions, traffic congestion is perceived as the most significant consequence (mean = 3.517), followed by effects on air quality (mean = 3.434) and noise pollution (mean = 3.386). These findings suggest that the negative consequences of car use are widely acknowledged, particularly in relation to urban traffic and environmental health. In contrast, the perceived benefits of replacing cars with public transport appear slightly less pronounced, with average scores ranging from 3.253 (for air quality) to 3.306 (for congestion). While respondents recognize the potential environmental advantages of public transport, they seem to attribute more weight to the harms caused by private cars than to the improvements brought by sustainable alternatives. Overall, the data suggest a stronger consensus on the negative environmental effects of car dependency than on the positive impact of increased public transport use.

Table 1. Profile of the respondents (n = 1373).

Sociodemographics	Subgroup	Respondents	% sample
Gender	Male	646	47.1
	Female	720	52.4
	Prefer not to say	7	0.5
Age	18–25	201	14.6
	26–40	417	30.4
	41–55	474	34.5
	56 and over	281	20.5
Level of education	Primary education	29	2.1
	Lower secondary education	145	10.6
	Upper secondary education	720	52.4
	Bachelor's degree/Master's degree	396	28.8
	P.h.D or postdoctoral	83	6.0
Employment status	Full-time/part-time employed	609	44.4
	Self-employed	188	13.7
	Housewife/Househusband	183	13.3
	Student	126	9.2
	Unemployed	183	13.3
	Retired	78	5.7
	Other	6	0.4
Income	Low	133	9.7
	Lower middle	778	56.7
	Upper middle	436	31.8
	High	26	1.9
Household structure	I live alone	136	9.9
	Two people	293	21.3
	Three people	414	30.2
	Four people	415	30.2
	Five people	115	8.4
Presence of people with disability in household	Yes	155	11.3
	No	1218	88.7
Residential location	Catania	754	54.9
	Outside Catania	619	45.1

The distribution of response frequencies for groups defined by the frequency of use of the TPL is reported in Table 4.

Following the Kruskal-Wallis test, which indicated significant differences ($p = 0.006$) in the perceptions of the impacts of private cars on air quality (ENVC1) across the groups defined by the frequency of public transport (PT) usage, a Dunn's post-hoc test with Bonferroni adjustment was performed to identify specific differences between the groups (Table 5).

Table 2. Transport-related variables.

Variable		Respondents	% sample
Public transport season ticket	Yes	346	25.2
	No	1027	74.8
Frequency of use of public transport	Non-users	675	49.1
	Occasional	474	34.5
	Frequent	224	16.3
Number of household cars	0	91	6.6
	1	618	45.0
	2	521	37.9
	3 or more	143	10.4
Driving license	Yes	1212	88.3
	No	161	11.7
Number of household motorcycles	0	823	59.9
	1	435	31.7
	2	89	6.5
	3 or more	26	1,9
Number of household bicycles	0	639	46.5
	1	435	31.7
	2	220	16.0
	3 or more	79	5.8
Number of household e-scooters	0	1181	86.0
	1	121	8,8
	2	38	2.8
	3 or more	33	2.4

The results showed that group 0 (non-users) gave significantly higher scores on the impact of private cars on air quality ($z = 2.93$, $p = 0.005$) compared to group 1 (occasional users). Group 2 (frequent users) had significantly higher scores compared to group 1 ($z = -2.47$, $p = 0.020$). No significant difference was found between non-users and frequent users ($p = 1.000$).

Thus, perceptions of the impact of private cars on air quality (ENVC1) vary significantly with the frequency of public transport usage, especially between occasional users and both frequent users and non-users. This finding suggests that environmental concern may not be limited to those who frequently use PT: non-users may also be aware of the environmental consequences of habitual car use, possibly due to their daily exposure to traffic-related air pollution. Conversely, frequent PT users may hold stronger pro-environmental values or experience the comparative benefits of PT, reinforcing their perception of the car's negative impacts. Occasional users, who engage with both modes, may lack a consistent evaluative framework, leading to more neutral or attenuated perceptions.

Table 3. Perceptions about impacts of private cars and PT on environmental issues.

Statements	1	2	3	4	5	mean
ENVC1: How much does habitual car use affect air quality?	6.1%	14.3%	34.1%	21.1%	24.4%	3.434
ENVC2: How much does habitual car use affect traffic congestion?	6.1%	11.3%	34.8%	20.2%	27.5%	3.517
ENVC3: How much does habitual car use affect noise pollution?	7.0%	13.8%	35.6%	20.7%	22.9%	3.386
ENVPT1: How much does replacing cars with public transport affect air quality?	7.4%	17.3%	37.3%	18.4%	19.5%	3.253
ENVPT2: How much does replacing cars with public transport affect traffic congestion?	6.9%	16.5%	36.4%	19.3%	20.8%	3.306
ENVPT3: How much does replacing cars with public transport affect noise pollution?	6.8%	17.3%	38.4%	18.7%	18.9%	3.256

In addition to ENVC1, the Kruskal-Wallis tests revealed significant differences between PT usage frequency groups for ENVC2 ($p = 0.003$), ENVPT1 ($p = 0.028$), and ENVPT3 ($p = 0.004$).

Post-hoc Dunn tests showed that for ENVC2 (perceived impact of car use on traffic congestion), significant differences emerged between non-users and occasional users ($z = 3.38$, $p = 0.001$), with non-users assigning higher impact scores. Using mainly private cars, non-users experience more congestion and perceive higher impacts.

Regarding ENVPT1 (perceived effect of replacing cars with public transport on air quality), a significant difference was found between occasional users and frequent users ($z = -2.66$, $p = 0.011$). Finally, for ENVPT3 (perceived effect of public transport on noise pollution), frequent users perceived significantly greater benefits compared to both non-users ($z = -2.72$, $p = 0.010$) and occasional users ($z = -3.27$, $p = 0.002$). Thus, frequent users reported significantly stronger beliefs in the positive effects of the use of PT on air quality and noise reduction. No significant group differences were observed in perceptions of car-related noise (ENVC3; $p = 0.144$) and PT's effect on congestion (ENVPT2; $p = 0.109$), suggesting that these impacts may be viewed as either less salient or more uniformly distributed among users regardless of their mobility habits.

Moreover, calculating effect sizes, we found that the comparison between occasional and frequent users regarding the perception of the positive environmental impact of public transport on noise pollution (ENVPT3) yielded the highest effect size ($r = 0.124$), which can be interpreted as small to medium. A small to medium effect size ($r = 0.101$) was also observed for ENVPT1, again between occasional and frequent users. The other pairwise comparisons with significant differences reported smaller effects.

The impact of gender on the response frequency distribution was further investigated (Table 6). The Mann-Whitney U test revealed significant gender differences in perception of the impacts of car use and the efficacy of PT in addressing environmental issues, although the effect sizes were found small (<0.1). Women were significantly more

Table 4. Perceptions about the impacts of private cars and public transport on environmental issues by frequency of use of PT (0: non-users, 1: occasional users, 2: frequent users).

Statements		1	2	3	4	5	mean
ENVC1: How much does habitual car use affect air quality?	0	5.6%	13.9%	31.3%	23.7%	25.5%	3.495
	1	6.1%	15.4%	39.5%	19.6%	19.4%	3.308
	2	7.6%	12.9%	31.3%	16.5%	31.7%	3.518
ENVC2: How much does habitual car use affect traffic congestion?	0	5.9%	11.0%	30.2%	22.2%	30.7%	3.607
	1	5.7%	11.2%	43.0%	17.7%	22.4%	3.399
	2	7.6%	12.5%	31.3%	19.6%	29.0%	3.5
ENVC3: How much does habitual car use affect noise pollution?	0	6.5%	13.8%	33.5%	24.7%	21.5%	3.409
	1	7.2%	13.8%	42.0%	15.8%	21.7%	3.316
	2	8.0%	15.2%	28.6%	18.8%	29.5%	3.464
ENVPT1: How much does replacing cars with public transport affect air quality?	0	8.1%	17.5%	35.6%	18.1%	20.7%	3.258
	1	6.8%	17.9%	42.0%	18.6%	14.8%	3.167
	2	6.7%	15.6%	32.6%	19.2%	25.9%	3.420
ENVPT2: How much does replacing cars with public transport affect traffic congestion?	0	7.7%	15.4%	35.1%	19.9%	21.9%	3.329
	1	6.5%	16.2%	42.2%	18.4%	16.7%	3.224
	2	5.4%	20.5%	28.1%	19.6%	26.3%	3.411
ENVPT3: How much does replacing cars with public transport affect noise pollution?	0	7.3%	18.4%	36.0%	20.0%	18.4%	3.239
	1	6.8%	16.9%	44.1%	16.7%	15.6%	3.175
	2	5.4%	14.7%	33.5%	19.2%	27.2%	3.482

likely than men to perceive habitual car use as detrimental to air quality (mean score = 3.519, $p = 0.005$) and noise pollution (mean score = 3.457, $p = 0.033$), and to believe that replacing cars with public transport would improve air quality (mean score = 3.332, $p = 0.007$) and reduce noise (mean score = 3.317, $p = 0.047$). These findings are consistent with previous research suggesting that women often report higher levels of environmental concern and greater sensitivity to environmental risks [20, 25]. However, small effect sizes suggest that these differences in perceptions are subtle and probably not relevant from a practical point of view. The absence of significant gender differences

Table 5. Dunn's test results for the differences in perceptions by PT usage frequency.

Comparison	ENVC1		ENVC2		ENVPT1		ENVPT3	
	z	p-value	z	p-value	z	p-value	z	p-value
0–1	2.932	0.005	3.376	0.001	1.347	0.267	0.932	0.527
0–2	−0.318	1.000	1.178	0.358	−1.752	0.120	−2.716	0.010
1–2	−2.474	0.020	−1.381	0.251	−2.663	0.011	−3.271	0.002

in the perception of car-related traffic congestion (ENVC2) and the impact of PT on congestion (ENVPT2) ($p > 0.1$) may reflect a shared experience of traffic-related issues across genders, or a more pragmatic view of congestion as a functional, rather than environmental, problem.

Table 6. Perceptions about impacts of private cars and PT on environmental issues by gender.

Statements		1	2	3	4	5	mean
ENVC1: How much does habitual car use affect air quality?	Male	7.9%	16.6%	33.6%	18.1%	23.8%	3.334
	Female	4.6%	12.4%	34.4%	23.8%	24.9%	3.519
ENVC2: How much does habitual car use affect traffic congestion?	Male	7.3%	12.7%	33.4%	19.5%	27.1%	3.464
	Female	5.0%	10.0%	36.1%	21.0%	27.9%	3.568
ENVC3: How much does habitual car use affect noise pollution?	Male	8.5%	15.0%	34.7%	20.6%	21.2%	3.310
	Female	5.4%	12.9%	36.5%	20.8%	24.3%	3.457
ENVPT1: How much does replacing cars with public transport affect air quality?	Male	9.0%	20.0%	36.1%	15.2%	19.8%	3.169
	Female	5.8%	15.1%	38.3%	21.4%	19.3%	3.332
ENVPT2: How much does replacing cars with public transport affect traffic congestion?	Male	8.4%	18.1%	34.7%	17.6%	21.2%	3.352
	Female	5.7%	15.3%	37.8%	20.8%	20.4%	3.35
ENVPT3: How much does replacing cars with public transport affect noise pollution?	Male	8.4%	18.6%	36.8%	18.6%	17.6%	3.186
	Female	5.4%	16.1%	39.7%	18.9%	19.9%	3.317

The relationship between age and environmental awareness was also analysed (Table 7). Overall, the mean scores across all age groups generally hover around 3 on the 5-point Likert scale, suggesting a moderate level of awareness regarding the environmental impacts of private car use and the potential benefits of public transport. However,

in some cases - particularly among younger respondents - mean scores fall below 3, indicating a skeptical stance. For instance, individuals aged 18–25 report a mean score below 3 for the belief that replacing cars with public transport would reduce air quality and traffic congestion, reflecting limited conviction about this specific benefit. These lower scores may indicate a lack of awareness or concern about some environmental issues among younger participants.

Table 7. Perceptions about impacts of private cars and PT on environmental issues by age

Statements		1	2	3	4	5	mean
ENVC1: How much does habitual car use affect air quality?	18–25	5.8%	13.2%	36.2%	21.1%	23.7%	3.229
	26–40	7.6%	15.4%	33.3%	21.9%	21.7%	3.439
	41–55	3.2%	11.4%	28.5%	24.2%	32.7%	3.348
	56 and over	5.8%	13.2%	36.2%	21.1%	23.7%	3.719
ENVC2: How much does habitual car use affect traffic congestion?	18–25	10.4%	11.9%	42.8%	14.9%	19.9%	3.219
	26–40	5.5%	10.8%	40.3%	17.0%	26.4%	3.480
	41–55	7.4%	12.7%	34.0%	20.7%	25.3%	3.439
	56 and over	1.8%	9.3%	22.4%	28.1%	38.4%	3.922
ENVC3: How much does habitual car use affect noise pollution?	18–25	11.9%	17.4%	33.8%	16.4%	20.4%	3.159
	26–40	7.4%	12.9%	39.1%	16.8%	23.7%	3.365
	41–55	7.2%	16.5%	34.4%	22.2%	19.8%	3.310
	56 and over	2.5%	8.2%	33.8%	27.0%	28.5%	3.708
ENVPT1: How much does replacing cars with public transport affect air quality?	18–25	11.9%	17.4%	33.8%	16.4%	20.4%	2.950
	26–40	7.4%	12.9%	39.1%	16.8%	23.7%	3.336
	41–55	7.2%	16.5%	34.4%	22.2%	19.8%	3.177
	56 and over	2.5%	8.2%	33.8%	27.0%	28.5%	3.473
ENVPT2: How much does replacing cars with public transport affect traffic congestion?	18–25	9.0%	27.4%	34.3%	16.4%	12.9%	2.970
	26–40	7.0%	14.6%	39.3%	16.3%	22.8%	3.333
	41–55	7.4%	13.9%	38.8%	21.7%	18.1%	3.293
	56 and over	4.6%	16.0%	29.5%	21.7%	28.1%	3.527
ENVPT3: How much does replacing cars with public transport affect noise pollution?	18–25	10.0%	20.9%	40.8%	15.4%	12.9%	3.005
	26–40	7.2%	13.9%	41.2%	16.5%	21.1%	3.305
	41–55	6.8%	18.1%	40.7%	18.1%	16.2%	3.190
	56 and over	3.9%	18.1%	28.5%	25.3%	24.2%	3.477

Significant generational differences in perceptions were found for all the items according to the Kruskal-Wallis tests ($p = 0.000$). Post-hoc Dunn tests (Table 8) revealed that older respondents (aged 56 and over) consistently report higher perceptions of the negative impacts of private car use (ENVC1–3) and of the positive environmental effects of shifting to public transport (ENVPT1–3), compared to younger age groups. These differences are statistically significant across most comparisons, particularly with the youngest group (18–25), for whom the z-values are strongly negative and p-values below 0.001 in all cases. Also, the effect sizes for this comparison (56 and over vs. 18–25) are

all over 0.2 and almost 0.3 in the case of ENVC2. These findings suggest that perceived negative environmental impacts of the use of private cars and benefits of public transportation appear to increase with age. One possible explanation is that older adults, due to their greater exposure to urban environmental problems, may be more aware of the consequences of car dependence. Meanwhile, younger individuals, who may rely less on private cars or have less direct exposure to their effects, might perceive these issues as less pressing or less tangible in everyday life.

Table 8. Dunn's test results for the differences in perceptions by age

Comparison	ENVC1		ENVC2		ENVC3		ENVPT1		ENVPT2		ENVPT3	
	z	p-value	z	p-value	z	p-value	z	p-value	z	p-value	z	p-value
[18–25]–[26–40]	−2.264	0.071	−2.361	0.055	−1.795	0.218	−3.772	0.001	−3.883	0.000	−3.166	0.005
[18–25]–[41–55]	−1.408	0.478	−2.093	0.109	−1.239	0.646	−2.324	0.061	−3.640	0.001	−1.987	0.141
[18–25]–[56 and over]	−4.670	0.000	−6.358	0.000	−4.812	0.000	−4.667	0.000	−5.369	0.000	−4.516	0.000
[26–40]–[41–55]	1.134	0.770	0.397	1.000	0.744	1.000	1.919	0.165	0.404	1.000	1.564	0.354
[26–40]–[56 and over]	−3.078	0.006	−4.997	0.000	−3.773	0.001	−1.387	0.496	−2.107	0.105	−1.885	0.178
[41–55]–[56 and over]	−4.168	0.000	−5.478	0.000	−4.533	0.000	−3.136	0.005	−2.521	0.0351	−3.329	0.003

Finally, the distribution of responses' frequency in percentile based on employment status is reported in Table 9.

The Kruskal-Wallis tests revealed significant differences between occupation groups for ENVC1 ($p = 0.010$), ENVC2 ($p = 0.046$) and ENVC3 ($p = 0.025$). No significant differences were found for all the items related to the perception of the impacts of replacing cars with public transport (ENVPT1: $p = 0.150$; ENVPT2: $p = 0.615$; ENVPT3: $p = 0.051$). Post-hoc Dunn tests (Table 10) with Bonferroni correction revealed a limited number of significant differences in environmental perceptions across occupational groups. Notably, retired individuals perceive significantly higher impacts of car use on air quality, congestion and noise pollution compared to other occupation groups. This is also confirmed by the mean scores reported for ENVC1–3: retired people gave higher scores on average than other occupation groups. Considering the effect sizes, small to medium effects were found for the comparisons between unemployed and retired people ($r = 0.238$) for ENVC1, and between students and retired people for ENVC1 ($r = 0.218$) and ENVC3 ($r = 0.202$).

These findings provide relevant insights for the development of DRT services, particularly in urban contexts, which seek to reduce car dependency through flexible and user-centred solutions. Widespread awareness of the environmental impacts of private car use, particularly in terms of congestion and air pollution, suggests a receptive ground for promoting alternative mobility services. DRT systems could take advantage of these perceptions by framing their offer not only in terms of convenience and flexibility, but also as a concrete response to environmental quality concerns.

Moreover, the perceptions observed across segmented user profiles - such as the heightened environmental concerns of frequent public transport users, women and older

Table 9. Perceptions about the impacts of private cars and public transport on environmental issues by occupation (1: Full-time/part-time employed; 2: Self-employed, 3: Unemployed, 4: Housewife/Househusband, 5: Student, 6: Retired).

Statements		1	2	3	4	5	mean
ENVC1: How much does habitual car use affect air quality?	1	7.9%	13.3%	34.0%	22.0%	22.8%	3.386
	2	4.8%	16.5%	35.6%	13.3%	29.8%	3.468
	3	6.0%	16.9%	35.0%	23.5%	18.6%	3.317
	4	4.9%	13.7%	35.5%	20.2%	25.7%	3.481
	5	4.8%	15.1%	38.1%	19.0%	23.0%	3.405
	6	1.3%	11.5%	17.9%	34.6%	34.6%	3.897
ENVC2: How much does habitual car use affect traffic congestion?	1	7.6%	9.7%	37.1%	18.7%	26.9%	3.478
	2	6.9%	12.8%	35.6%	16.0%	28.7%	3.468
	3	5.5%	12.6%	36.6%	20.8%	24.6%	3.464
	4	3.8%	10.9%	31.7%	21.9%	31.7%	3.667
	5	5.6%	15.1%	34.9%	19.8%	24.6%	3.429
	6	1.3%	12.8%	16.7%	38.5%	30.8%	3.846
ENVC3: How much does habitual car use affect noise pollution?	1	8.2%	14.3%	36.0%	21.2%	20.4%	3.312
	2	4.8%	16.5%	35.1%	15.4%	28.2%	3.457
	3	8.2%	10.4%	39.3%	21.9%	20.2%	3.355
	4	4.9%	10.4%	39.9%	21.3%	23.5%	3.481
	5	9.5%	19.0%	30.2%	15.1%	26.2%	3.294
	6	1.3%	12.8%	23.1%	33.3%	29.5%	3.769
ENVPT1: How much does replacing cars with public transport affect air quality?	1	8.9%	15.1%	35.6%	18.2%	22.2%	3.297
	2	5.3%	17.0%	39.4%	16.0%	22.3%	3.330
	3	6.6%	20.2%	43.7%	15.8%	13.7%	3.098
	4	5.5%	17.5%	38.3%	21.3%	17.5%	3.279
	5	7.9%	22.2%	36.5%	20.6%	12.7%	3.079
	6	7.7%	21.8%	25.6%	23.1%	21.8%	3.295
ENVPT2: How much does replacing cars with public transport affect traffic congestion?	1	8.2%	14.1%	36.5%	18.4%	22.8%	3.335
	2	4.8%	19.7%	37.8%	13.8%	23.9%	3.324
	3	5.5%	16.4%	41.5%	21.9%	14.8%	3.240
	4	6.0%	15.3%	35.0%	24.6%	19.1%	3.355

(*continued*)

Table 9. (*continued*)

Statements		1	2	3	4	5	mean
	5	7.9%	21.4%	31.7%	20.6%	18.3%	3.198
	6	6.4%	24.4%	29.5%	19.2%	20.5%	3.231
ENVPT3: How much does replacing cars with public transport affect noise pollution?	1	8.2%	14.8%	36.8%	20.2%	20.0%	3.291
	2	3.7%	14.9%	44.1%	16.5%	20.7%	3.356
	3	7.1%	20.2%	41.0%	17.5%	14.2%	3.115
	4	6.0%	15.3%	37.7%	21.3%	19.7%	3.333
	5	7.9%	21.4%	42.1%	13.5%	15.1%	3.063
	6	2.6%	34.6%	23.1%	17.9%	21.8%	3.218

Table 10. Dunn's test results for the differences in perceptions by occupation.

Comparison	ENVC1		ENVC2		ENVC3	
	z	p-value	z	p-value	z	p-value
1–2	−0.591	1.000	0.159	1.000	−1.260	1.000
1–3	0.991	1.000	0.208	1.000	−0.538	1.000
1–4	−0.791	1.000	−1.787	0.554	−1.580	0.855
1–5	0.147	1.000	0.670	1.000	0.290	1.000
1–6	−3.604	0.002	−2.590	0.072	−3.211	0.010
2–3	1.279	1.000	0.042	1.000	0.569	1.000
2–4	−0.167	1.000	−1.579	0.857	−0.271	1.000
2–5	0.552	1.000	0.455	1.000	1.158	1.000
2–6	−2.852	0.033	−2.411	0.119	−2.087	0.277
3–4	−1.436	1.000	−1.602	0.819	−0.833	1.000
3–5	−0.599	1.000	0.412	1.000	0.637	1.000
3–6	−3.816	0.001	−2.426	0.114	−2.509	0.091
4–5	0.699	1.000	1.865	0.466	1.394	1.000
4–6	−2.712	0.050	−1.189	1.000	−1.871	0.461
5–6	−3.103	0.014	−2.614	0.067	−2.874	0.030

individuals - highlight the importance of tailoring DRT communication and service design to specific demographic segments.

4 Conclusions and Further Research

Concerns about climate change and pollution from greenhouse gas emissions, especially from car transport, are particularly evident in cities. Therefore, sustainable mobility policies and actions that aim to increase citizens' environmental awareness are crucial for building sustainable and resilient cities. Deliberate action in the planning of cities and territories can contribute directly or indirectly to improve overall health and wellbeing [29]. To this end, knowing the degree of environmental awareness and the resulting transport mode choices become important to identify the best possible policy actions. The results presented in this paper, although representing only a part of the more complete survey carried out, concerning the degree of environmental awareness in relation to urban transport, could become important elements for implementing effective urban planning actions. The general perception of the respondents reveals a good level of awareness of the environmental impacts associated with the habitual use of private cars and trust in public transport as a possible solution with average scores above 3. The results of the statistical tests showed that there is a slight difference between men and women in the perception of the impacts on air and noise pollution of habitual car use and in the perception of the benefits deriving from the shift towards public transport. This slight difference, although significant, does not suggest the application of differentiated strategies between men and women.

Frequent PT users and non-users do not seem to have given statistically very different scores, highlighting how the use of public transport may not be linked to greater environmental awareness in this context. Significant differences between frequent users and non-users can be observed only when considering the perceived effect of the switch to public transport on noise pollution. Moreover, occasional users seemed to assign significantly lower scores than frequent users, showing a lower environmental concern. Finally, retired people and people over 56 seemed to be more environmentally conscious. Thus, campaigns targeting students can be promoted to increase environmental awareness among younger people.

By incorporating user perception into the planning and promotion of DRT systems, it becomes possible to design more effective and inclusive strategies that are aligned with both behavioral trends and broader sustainability goals. As suggested by the UN Habitat and WHO (2020) International Guidelines (IG-UTP) [30], these results would be a valid support to develop the Urban and Territorial Planning for improved environments and wellbeing. The IG-UTP advocates for urban and territorial planning as an integrated and participatory decision-making process to plan and manage our cities and territories in a holistic manner.

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References

1. UN: Our Common Future. The World Commission on Environment and Development, Oxford University Press (1987)
2. UN: Transforming Our World: The 2030 Agenda For Sustainable Development. United Nations. Department of Economic and Social Affairs: New York, NY, USA (2015)
3. EC: The European Green Deal. 2019. Available online: EUR-Lex - 52019DC0640 - EN - EUR-Lex (2019). Accessed 16 Dec 2024
4. EEA: Greenhouse gas emissions from transport in Europe, 31 October 2024. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport?activeAccordion=ecdb3bcf-bbe9-4978-b5cf-0b136399d9f8
5. Mims: Rapporto STEM. Decarbonizzare i trasporti (2022)
6. U.N. Habitat: Urbanization and development: emerging futures. Professionale case management (2016). https://doi.org/10.1097/NCM.0000000000000166
7. Sturiale, L., Ignaccolo, M., Torrisi, V., Scuderi, A.: An integrated approach for the co-governance of sustainable and resilient cities: a focus on Green Infrastructures and Transport Mobility in Catania (Italy). In: Gervasi, O., et al. (eds.) Computational Science and Its Applications – ICCSA 2023 Workshops: Athens, Greece, July 3–6, 2023, Proceedings, Part II, pp. 213–230. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-37108-0_14
8. Sturiale, L., Torrisi, V., Cocuzza, E., Ignaccolo, M.: A possible model of resilient and environment-friendly transport: assessment of users' propensity towards demand responsive transit (DRT) service. In: Calabrò, F., Madureira, L., Morabito, F.C., Piñeira Mantiñán, M.J. (eds.) Networks, Markets & People. Lecture Notes in Networks and Systems, vol. 1187, pp. 365–375. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-74704-5_36
9. Santos, G., Behrendt, H., Maconi, L., Shirvani, T., Teytelboym, A.: Part I: externalities and economic policies in road transport. Res. Transp. Econ. **28**(1), 2–45 (2010)
10. Sovacool, B.K., Kim, J., Yang, M.: The hidden costs of energy and mobility: a global meta-analysis and research synthesis of electricity and transport externalities. Energy Res. Soc. Sci. **72**, 101885 (2021)
11. Chatziioannou, I., Alvarez-Icaza, L., Bakogiannis, E., Kyriakidis, C., Chias-Becerril, L.: A structural analysis for the categorization of the negative externalities of transport and the hierarchical organization of sustainable mobility's strategies. Sustainability **12**(15), 6011 (2020)
12. Rotaris, L., Danielis, R.: The impact of transportation demand management policies on commuting to college facilities: a case study at the University of Trieste, Italy. Transp. Res. Part A Policy Pract. **67**, 127–140 (2014)
13. Cattaneo, M., Malighetti, P., Morlotti, C., Paleari, S.: Students' mobility attitudes and sustainable transport mode choice. Int. J. Sustain. High. Educ. **19**, 942–962 (2018)
14. Collins, C.M., Chambers, S.M.: Psychological and situational influences on commuter-transport-mode choice. Environ. Behav. **37**, 640–661 (2005)
15. Crotti, D., Grechi, D., Maggi, E.: Proximity to public transportation and sustainable commuting to college. A case study of an Italian suburban campus. Case Stud. Transp. Policy **10**, 218–226 (2022)
16. Ramos, E.M.S., Bergstad, C.J., Nassen, J.: Understanding daily car use: driving habits, motives, attitudes, and norms across trip purposes. Transp. Res. Part F Traff. Psychol. Behav. **68**, 306–315 (2020)
17. Nordfjærn, T., Egset, K.S., Mehdizadeh, M.: "Winter is coming": psychological and situational factors affecting transportation mode use among university students. Transp. Policy (Oxf) **81**, 45–53 (2019)

18. Kamargianni, M., Polydoropoulou, A.: Hybrid choice model to investigate effects of teenagers' attitudes toward walking and cycling on mode choice behavior. Transp. Res. Rec. **2382**, 151–161 (2013)
19. Ingvardson, J.B., Thorhauge, M., Kaplan, S., Nielsen, O.A. Raveau, S.: Incorporating psychological needs in commute mode choice modelling: a hybrid choice framework. Transportation (Amst) 1–29 (2021)
20. Jia, N., Li, L., Ling, S., Ma, S., Yao, W.: Influence of attitudinal and low-carbon factors on behavioral intention of commuting mode choice– a cross-city study in China. Transp. Res. Part A Policy Pract. **111**, 108–118 (2018)
21. Sturiale, L., Scuderi, A., Timpanaro, G.: Citizens' perception of the role of urban nature-based solutions and green infrastructures towards climate change in Italy. Front. Environ. Sci. **11**, 1105446 (2023)
22. Scuderi, A., Sturiale, L.: Evaluations of social media strategy for green urban planning in metropolitan cities. In: Calabrò, F., Spina, L.D., Bevilacqua, C. (eds.) ISHT 2018. SIST, vol. 100, pp. 76–84. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-92099-3_10
23. Ming, Y., Deng, H., Wu, X.: The negative effect of air pollution on people's pro-environmental behavior. J. Bus. Res. **142**, 72–87 (2022)
24. Sottile, E., Tuveri, G., Piras, F., Meloni, I.: Modelling commuting tours versus non-commuting tours for university students. A panel data analysis from different contexts. Transp. Policy (Oxf) **118**, 56–67 (2022)
25. Vazquez-Paja, B., Feo-Valero, M., del Saz-Salazar, S.: Environmental awareness and transportation choices: a case study in Valencia, Spain. Transp. Res. Part D **137**, 104487 (2024)
26. National Institute of Statistics (ISTAT): Bilancio demografico mensile anno 2023 (dati provvisori), su demo.istat.it, ISTAT, 7 aprile 2023
27. 35rd Quality of Life Survey from Il Sole 24 ore (2024). https://lab24.ilsole24ore.com/qualita-della-vita/
28. Okoye, K., Hosseini, S.: Mann-Whitney U test and Kruskal-Wallis H test statistics in R. In: Okoye, K., Hosseini, S. (eds.) R programming, pp. 225–246. Springer, Singapore (2024). https://doi.org/10.1007/978-981-97-3385-9_11
29. Cohen, J.: Statistical Power Analysis for the Behavioral Sciences, 2nd edn. Routledge, New York (1988)
30. UN Habitat and WHO: Integrating health in urban and territorial planning: a sourcebook. Geneva: UN-HABITAT and World Health Organization, 2020. 20002_Integrating Health in Urban and Territorial Planning A Sourcebook (2020)