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Environmental awareness and transportation choices: A case study in Valencia, Spain

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ABSTRACT

This research examines the role of environmental awareness and pro-environmental actions on transport mode choice among university students in Valencia, Spain. Based on data obtained through 524 face-to-face interviews, a hybrid discrete choice model was developed to identify the main determinants and the most effective policy measures to achieve sustainable transportation.

Our findings highlight a disassociation between environmental awareness and actual pro-environmental actions. While the latent variable of environmental awareness has no significant effect, pro-environmental actions do positively affect the probability of using sustainable modes.

In terms of policy recommendations, the most effective measures to reduce car dependency would be those affecting transit time, such as reducing parking space in campus surroundings or facilitating transfers in the case of public transportation. Finally, policies aimed at increasing sustainable transportation should not only focus on raising awareness but also on promoting involvement in non-transport-related environmental actions.

1. Introduction

Over the past few decades, developed economies have been strengthening efforts to achieve a reduction in their levels of emissions and, as a result, the social and environmental impact caused by the daily activity of their citizens. Much of this impact is concentrated in urban environments, which, although they barely represent 3 % of the earth's surface, are responsible for 75 % of carbon emissions caused by human activity (U.N. Habitat, 2016).

Within such environments, a significant part of the emissions arises from transport flows. According to OECD estimates (International Transport Forum, 2017), motorized mobility in cities could increase by 94 % between 2015 and 2050, which would lead to a 26 % increase in CO_2 emissions from urban activity. It is thus essential to develop sustainable mobility patterns that make it possible to minimize the negative impact of all transport and distribution activities in cities. Accordingly, this has become one of the priority objectives of urban interventions aimed at ensuring compliance with the Paris Agreement and the achievement of the Sustainable Development Goals.

Within the different commutes in urban areas, those to certain locations, such as university campuses, are of special relevance since these areas become gravitational centres around which important mobility flows are generated. Universities are interesting case studies both because of the large number of students and staff commuting to them (Tolley, 1996) and because of their ability to attract

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social dynamics within their environment (Rotaris and Danielis, 2014).

Moreover, the control that university managers usually have over their surrounding environment (car parks or road network) (Duque et al., 2014) allows them to directly manage sustainable mobility actions, in addition to any that may have already been carried out by the local or regional authorities. Furthermore, students generally have less access to private vehicles and are more likely to consider and use active transport modes or public transport (Bonham and Koth, 2010; Limanond et al., 2011; Whalen et al., 2013). Hence, university campuses are suitable spaces to test new policies aimed at achieving sustainable mobility (Balsas, 2003; Thigpen, 2019).

The measures implemented by university managers to help promote sustainable mobility patterns in commutes to and from their campuses are also expected to ultimately have an impact beyond their own environment. In general, after leaving university, graduates are expected to maintain behaviors, such as their choice of transport mode, that were consolidated during their time at the university (Limanond et al., 2011; Shannon et al., 2006).

Even though university students are a group with complex and unique behavior compared to that of the general population (Limanond et al., 2011; Zhou, 2016), they continue to be underrepresented in this type of study and there is still relatively little empirical evidence on the issue (Balsas, 2003; Zhou, 2012).

This research seeks to add to the empirical evidence available, focusing on the campuses of the two public universities in the city of Valencia (Spain): University of Valencia and Polytechnic University of Valencia. This city is a case study of particular relevance since its topography may enhance the use of active modes, specially cycling (Piras et al., 2021), and it has a generally mild climate and an extensive public transport network. Likewise, its campuses allow the analysis of various different situations: one campus is close to the city centre (campus of Blasco Ibáñez) with limited parking and wide public transport coverage; two campuses (Vera and Tarongers) are located in more peripheral areas of the city, with plenty of parking space available and good public transport connections; and lastly, the campus of Burjassot is located in a nearby town where parking is plentiful, but public transport is limited.[1]

Nonetheless, the primary objective of this research is to investigate the influence of environmental awareness and pro-environmental actions on the transportation mode choices of university students. Building on this, and the other determinants identified, the goal is to enable a more effective design of current mobility policies.

In order to delve into the role that a latent variable such as environmental awareness plays in this choice, a hybrid choice model was specified (Ben-Akiva et al., 2002, 1999; Hess and Daly, 2014; McFadden, 1986). Methodologically, the use of such models to identify the role that certain abstract constructs, such as attitudes or perceptions, play in the mode choice process has been gaining traction. Recently, in the field of urban transport, there has been a proliferation of applications which include latent variables that capture the convenience of using certain modes (Gutiérrez Torres, 2021) the greater or lesser risk aversion or perceived safety (Kamargianni et al., 2015), willingness to use active modes (Kamargianni and Polydoropoulou, 2013), service level perceptions (Ingvardson et al., 2021) or environmental awareness (Sottile et al., 2015).

It could be expected that individuals who exhibit a higher level of environmental awareness will correspondingly attach greater significance to mitigating the environmental consequences stemming from their daily actions and decisions. Consequently, such individuals would likely manifest a higher propensity to employ the most ecologically sustainable modes of transportation (Bonham and Koth, 2010). It is worth noting the distinction made in the related literature between the environmental awareness construct —an individual's awareness of the current state of the natural environment and its possible evolution due to human intervention— and pro-environmental practices or actions —acquired habits or actions that facilitate environmental protection. While the latter may be directly observable, environmental awareness is a latent variable. Although a positive correlation might be expected between awareness and environmental actions, empirical evidence shows a value-action gap; that is, even when individuals show high levels of concern about the environment, this does not always lead to changes in their behavior (Blake, 1999; Kollmuss and Agyeman, 2002; Marcell et al., 2004). This value-action gap has also been identified for students (Chaplin and Wyton, 2014), providing evidence of a dissociation between awareness and environmental behaviors or actions (Bell et al., 2008; Sabourin and Lamarche, 2001).

This paper specifically investigates whether this value-action gap exists in the case of university students' transportation mode choices. The contribution of this study lies in its empirical analysis focused on environmental awareness and actions, which provides valuable insights for policymakers looking to promote sustainable transportation within university settings.

The remainder of this paper is organized as follows. Section 2 presents the review of the literature. Section 3 describes the methodology and data used. The main results are detailed in Section 4, focusing on the possible outcomes of different policy actions that could change students' behavior. Finally, the main conclusions drawn from the analysis and avenues for further research are discussed in Section 5.

2. Literature review

This research focuses on identifying determinants of university students' transport mode choice, with particular emphasis on variables linked to environmental awareness and pro-environmental behaviors, in order to recommend the most effective policy actions. The review of the literature thus focuses on this aspect.

First of all, there are a series of attributes —variables specific to each transportation alternative— that are traditionally identified as determinants of university students' mode choice. These include cost (Collins and Chambers, 2005; Danaf et al., 2014; Rodríguez and

[1] Scientific and technical programs are offered at the Vera and Burjassot campuses, while the Blasco Ibáñez campus offers humanities and medicine, and the Tarongers campus focuses on social sciences.

Joo, 2004; Rotaris and Danielis, 2014; Zhou, 2012) and time (Collins and Chambers, 2005; Klöckner and Friedrichsmeier, 2011), the latter is usually identified as one of the main barriers to the use of sustainable modes (Miralles-Guasch and Domene, 2010; Nguyen-Phuoc et al., 2018; Shannon et al., 2006; Stein and Rodrigues da Silva, 2018) and is occasionally broken down into transit time, access time and frequency or punctuality of the service (Miralles-Guasch and Domene, 2010; Shannon et al., 2006). Other attributes analysed, although less frequently, are comfort (Cattaneo et al., 2018; Kaplan, 2015; Nordfjærn et al., 2019; Whalen et al., 2013), safety (Miralles-Guasch and Domene, 2010; Stein and Rodrigues da Silva, 2018) and connectivity (Crotti et al., 2022; Romanowska et al., 2019; Zhou, 2012), in terms of either the availability of a direct connection to the campus or the availability of different transportation options within a certain radius.

Trip characteristics and the surroundings during the trip also influence the decision-making process. Notable among these characteristics are the distance (Cattaneo et al., 2018; Crotti et al., 2022), the time of day at which the commute occurs (Crotti et al., 2022; Delmelle and Delmelle, 2012) and the frequency (Olawole and Olapoju, 2016; Zhou, 2014). Other more general characteristics of the environment, such as pollution or weather, can also condition the choice. Cattaneo et al. (2018) showed that living in locations with higher levels of pollution fosters the use of public transport or active modes, while weather conditions can be a disadvantage for the use of more sustainable modes (Shannon et al., 2006). For example, in the study by Stein and Rodrigues da Silva (2018), unfavourable weather conditions were identified as the most important barrier to cycling and walking.

Recently, there has been increasing attention paid to environmental variables because of the effect they can have on the level of service of the different transport alternatives, specially after COVID-19 (Song et al., 2023), and also due to public authorities' capacity to establish measures that affect these variables. Since the environment of the journey is not a one-dimensional variable, but rather is determined by a combination of multiple factors, certain studies analyse the individual effect of specific characteristics of the environment (Lavery et al., 2013; Rodríguez and Joo, 2004; Sottile et al., 2022) while others choose to build indicators—of varying degrees of sophistication—that incorporate several of these factors simultaneously (Vale et al., 2018).

Although there tends to be consensus about the impact of commute attributes on the utility of the different modes, there is a greater diversity of results regarding the effect of socioeconomic variables. Thus, for example, in the case of gender, while some studies have found that men show greater willingness to use active modes (Delmelle and Delmelle, 2012; Zhou, 2016), others obtain the opposite (Nguyen-Phuoc et al., 2018; Zhou, 2012). Regarding age, even though the range of variation in university students is usually limited, it has been identified as a main determinant of the choice in several studies (Cattaneo et al., 2018; Delmelle and Delmelle, 2012; Zhou, 2016, 2012). Socioeconomic characteristics such as area of studies (Cattaneo et al., 2018), family income (Danaf et al., 2014; Nguyen-Phuoc et al., 2018) or type of residence (Nguyen-Phuoc et al., 2018; Zhou, 2014) may also be relevant. Nonetheless, it should be noted that cultural differences condition the choice set and, as a consequence, mobility patterns.

In recent years, the inclusion of latent variables such as attitudes or perceptions has represented a qualitative leap in choice studies. The definition, measurement and incorporation of this type of variable into the model is complex: not only are these variables multidimensional in nature, but they are also not directly observable. To date, very few empirical studies of the mode choice of university students have included such variables, although approximations have been made with the perceived impact on health (Shannon et al., 2006; Stein and Rodrigues da Silva, 2018), importance given to physical exercise (Nordfjærn et al., 2019), perception of control and ability to use alternative modes (Klöckner and Friedrichsmeier, 2011) or, in line with the objective of this study, environmental awareness.

Environmental awareness has previously been identified as a significant variable in studies on urban transport mode choice for the general population (Jia et al., 2018; Liu et al., 2017). Regarding university students' mode choice, an early study was carried out by Collins and Chambers (2005) with a model focused on psychological aspects of environmental awareness, concluding that the potential policy actions that could prompt a shift from private vehicles to more sustainable transport modes would differ between students with pro-social environmental beliefs and values and those who do not hold such values. Nordfjærn et al. (2019) also studied this latent variable —in their case, using the value, norms and beliefs model (Schwartz and Howard, 1981)— finding that students who seemed to be more aware of the negative environmental impact of the car had a higher probability of using active modes. Surprisingly, however, students who felt more responsible for their environmental behavior were the ones who used the car the most to get to campus. Lastly, Cattaneo et al. (2018) included a sustainability variable from a less psychological perspective, incorporating as an explanatory variable the importance that the student attributed to sustainability when choosing a mode of transport. They found that the greater the importance given to sustainability, which can be understood as an approximation of environmental awareness, the greater the probability of choosing public transport or active modes.

3. Methods and data

3.1. Questionnaire and data collection

In order to achieve the research objectives, a survey was conducted with a sample of students from the four campuses of the two public universities in the city of Valencia. The data were obtained by conducting random face-to-face interviews, at different locations and in different time slots. The questionnaire had three blocks that allowed us to obtain information about the socioeconomic characteristics of the students and their commute to campus; about their available choice set, level of service of the mode of transport chosen (cost, time, frequency, etc.); and about their environmental awareness.

A total of 524 interviews were carried out, with the final number of observations after checking all the data standing at 499. The data collection was carried out between the months of November 2018 and May 2019, obtaining a representative sample in terms of students per campus, gender, country of origin, paid work and scholarship, but with a slight bias in terms of the level of studies (see

Table 1).

Table 2 shows the characteristics of the sample based on the main socioeconomic variables collected and the modal shares.

3.2. Hybrid choice model

This study uses a hybrid logit model (Ben-Akiva et al., 1999; Ben-Akiva et al., 2002; Hess and Daly, 2014; McFadden, 1986) incorporating a latent variable capturing the student's environmental awareness.

By incorporating latent variables we can rewrite the representative utility function for an individual n and an alternative i associated with the discrete choice model as

$$V_{ni} = \sum_k \beta_{ik} x_{nik} + \sum_l \gamma_{il} \eta_{nil},$$

where x_{nik} are the directly observable variables, η_{nil} are the latent variables and β_{ik} and γ_{il} are the coefficients or parameters to be estimated.

Since latent variables are not directly observable, it is necessary to estimate their value as a function of other variables that are in fact observable, called indicators. Indicators are usually observed by the response that the decision-maker, the student, gives regarding their degree of agreement about a number of statements. Once the information from the indicators is available in order to estimate the latent variable, a MIMIC (multiple indicators, multiple causes) model is frequently used (Bahamonde-Birke et al., 2017). A MIMIC model is made up of two equations: the structural equation, which explains how the latent variables are related to the attributes and/or socioeconomic characteristics of the transport mode alternatives and/or of the individuals; and the measurement equation, which explains how the indicators are related to the latent variables.

The measurement equation, in which the latent variable is an explanatory variable of the results obtained for each decision-maker, takes the following form:

$$I_i = \Lambda \eta_i + \xi_i$$

where I_i is a vector of indicators for each decision-maker i, Λ is a matrix of parameters to be estimated, η_i is the vector of latent variables and ξ_i is the vector of random terms.

Secondly, the structural equation is defined as:

$$\eta_i = \Gamma \omega_i + \zeta_i$$

where η_i is the vector of latent variables as mentioned above, Γ is the matrix of parameters to be estimated, ω_i is a vector of attributes and/or socioeconomic variables and, lastly, ζ_i is a vector of error terms.

In this study, the complete estimation of the hybrid model (Fig. 1) has been carried out sequentially. The MIMIC model has been estimated using the robust maximum likelihood method (Satorra and Bentler, 1994; Yuan and Bentler, 1998), which was developed for approximately continuous but potentially non-normal variables, such as indicators that follow Likert scales with five or more response categories, as in this case. EQS software v6.4. was used to estimate the value of the latent variable, environmental awareness, which was later introduced into the discrete choice model —mixed logit with error component— in order to assess what role, if any, this variable, together with the other variables of interest, may play in transport mode choice for students travelling to the university campus.

Table 1

Distribution of students from public universities in Valencia (population and sample distribution, academic year 2018–2019).

	POPULATION			**SAMPLE**		
	Women	**Men**	**Total**	**Women**	**Men**	**Total**
De Vera (UPV)	35.9 %	64.1 %	32.5 %	41.3 %	58.7 %	34.2 %
Tarongers (UV)	63.7 %	36.3 %	28.2 %	63.3 %	36.7 %	26.5 %
Blasco Ibáñez (UV)	67.3 %	32.7 %	26.0 %	63.5 %	36.5 %	26.1 %
Burjassot (UV)	51.2 %	48.8 %	13.3 %	42.0 %	58.0 %	13.2 %
Total	53.4 %	46.6 %	100.0 %	53.0 %	46.9 %	100.0 %
	Undergraduate	**Postgraduate**	**Total**	**Undergraduate**	**Postgraduate**	**Total**
Level of studies	76.5 %	23.5 %	100.0 %	88.7 %	11.3 %	100.0 %
	Spain	**Other**	**Total**	**Spain**	**Other**	**Total**
Country of origin	90.4 %	9.6 %	100.0 %	89.6 %	10.4 %	100.0 %
	Yes	**No**	**Total**	**Yes**	**No**	**Total**
Work & Study*	26.2 %	73.8 %	100.0 %	27.8 %	72.2 %	100.0 %
Scholarship*	30.8 %	69.2 %	100.0 %	38.8 %	61.2 %	100.0 %

Source: Own elaboration based on data form the Ministry of Education and Science (2019) and University of Valencia (2019).

* Population and sample quota exclusively for students at UV.

Table 2
Socioeconomic characteristics of the sample and modal shares.

GENDER	**MEN**	**WOMEN**				
	46.9 %	53.1 %				
AGE	**< 21**	**22—25**	**26–30**	**> 30**		
	63.0 %	28.1 %	6.9 %	2.1 %		
COUNTRY OF ORIGIN	**SPAIN**	**EUROPE**	**OTHER**			
	88.9 %	3.2 %	7.8 %			
TYPE OF RESIDENCE DURING THE ACADEMIC COURSE	**FAMILY**	**SHARED**	**OWN**	**RESIDENCE**		
	61.8 %	31.5 %	4.0 %	2.7 %		
PLACE OF RESIDENCE DURING THE ACADEMIC COURSE	**VALENCIA**		**PERIPHERY**		**OTHER**	
	62.6 %		24.2 %		13.2 %	
FAMILY INCOME ASSESSMENT	**LOW**	**MEDIUM**	**HIGH**			
	4.2 %	82.3 %	13.5 %			
SCHOLARSHIP	**YES**	**NO**				
	39.7 %	60.3 %				
WORKS	**YES**	**NO**				
	25.0 %	75.0 %				
FREQUENCY OF PHYSICAL ACTIVITY	**LOW**	**MODERATE**	**FREQUENT**	**CONTINUOUS**		
	23.7 %	33.8 %	35.9 %	6.7 %		
TYPE OF STUDIES	**UNDERGRADUATE**		**POSTGRADUATE**			
	88.7 %		11.3 %			
MODE SHARES	**WALK**	**BIKE**	**OWN VEH.**	**METRO**	**BUS**	**RAIL**
	26.5 %	9.7 %	21.9 %	21.9 %	15.4 %	4.5 %

Source: Own elaboration.

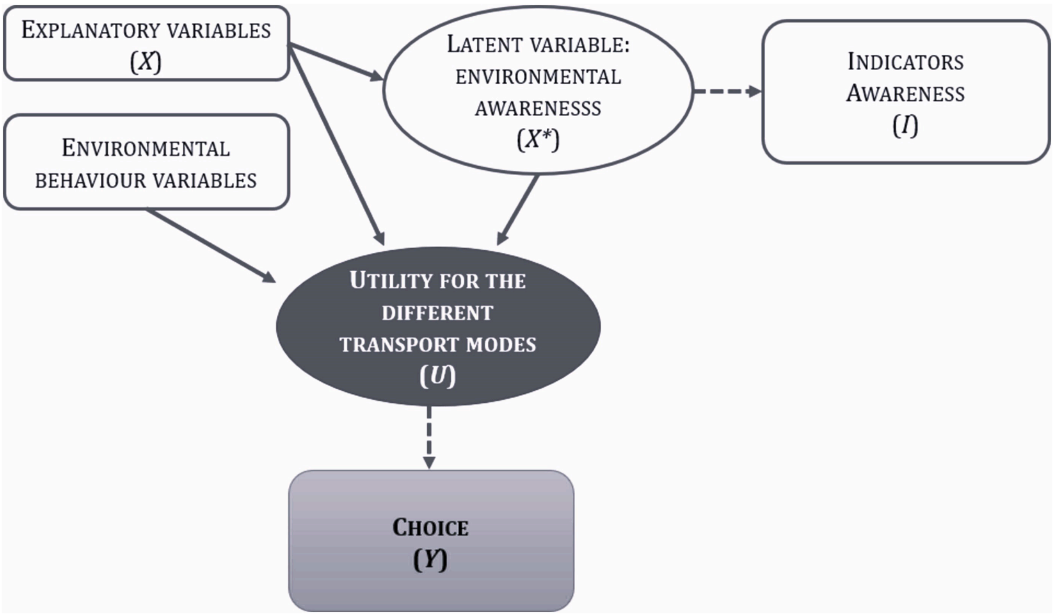

Fig. 1. Diagram of the hybrid mode choice model. *Source*: Own elaboration.

4. Results

4.1. Estimation of the latent variable

Fig. 2 shows the questions included in the questionnaire to determine students' environmental awareness and behavior. These questions included the six indicators —adapted from the instrument by Diekmann and Preisendörfer (2003)— used in the measurement equation to approximate environmental awareness, as well as those aimed at obtaining additional information about the students' assessment of the environment and any pro-environmental actions they may engage in. While the possibility of treating these pro-environmental actions as a latent variable was considered, the lack of prior validation for these indicators, which may lead to bias (DeVellis and Thorpe, 2021; Podsakoff et al., 2003), and the presence of dichotomous variables, which are unsuitable for factor analysis (Bollen, 2014; MacCallum et al., 1999), led us to discard this approach. Including pro-enviornmental actions variables in the discrete choice model is considered to provide an easier and more accurate interpretation without introducing potential biases or

Environmental awareness indicators
I1. I am afraid when I think about environmental conditions for future generations.
I2. If we continue our current style of living, we are approaching an environmental catastrophe.
I3. In my opinion, environmental problems are greatly exaggerated by proponents of the environmental movement.
I4. It is still true that politicians do much too little to protect the environment
I5. Environmental protection measures should be carried out, even if this reduces the number of jobs in the economy
I6. Climate change is already a reality as average temperatures have increased and climate disasters are becoming more common (floods, prolonged droughts, hurricanes, etc.)

Direct assessment of awareness
DA1. How would you rate the importance that conservation and protection of the environment has for you at the moment?
DA2. Rate (from 1 to 5) the importance given to environmental impact when choosing a transportation mode to get to campus.

Actions (behaviors) in favor of the environment
B1. Do you frequently carry out recycling activities (paper and cardboard, glass, plastic)?
B2. Do you frequently carry out activities aimed at saving energy and water in your home? (Showering instead of bathing, turning off the lights when not necessary, turning off the water tap while brushing your teeth, disconnecting devices on standby, etc.)
B3. Are you part of any nature defense organization or group such as Greenpeace or Adena-WWF?

Environment assessment
EA1. How would you rate the level of air pollution in the city of Valencia?
EA2. How would you rate your knowledge and level of information about the actions that are being carried out in the city of Valencia to achieve more sustainable transportation?
EA3. Do you agree with the actions carried out in the city of Valencia to promote sustainable transport? (pedestrianization, prohibition of parking in the bus lane, expansion of bike lanes available, etc.)

Fig. 2. Questions about environmental awareness and behavior included in the questionnaire. *Source*: Own elaboration.

estimation challenges.

As recommended (Brown, 2015), before estimating the MIMIC model for the environmental awareness latent variable, a confirmatory factor analysis was carried out to verify that all indicators had been adequately included in the measurement equation and that the instrument does in fact capture this latent variable. According to the results obtained, all the indicators except the fourth one (I4) were significant and showed the expected sign; I4 was thus eliminated. After the elimination of the fourth indicator, all weights were greater than 0.5.

Both the confirmatory factor analysis and the MIMIC model estimation were done with the software EQS v6.4. The final results obtained for the best model are shown in Table 3. Three variables were included in the final model —gender, living in the family home and perceived level of family income—, with these three being the only ones that reached a significance of at least 5 %. The model is well-fitted: CFI is greater than 0.95, the root mean square error of approximation (RMSEA) is less than 0.05 and the probability of the χ^2 statistic is less than 0.05, meaning we can reject the null hypothesis that the relationships established in the model are not significant.

Female students show higher levels of environmental awareness, a finding reflected in the literature (Luchs and Mooradian, 2012; Scannell and Gifford, 2011). However, living in the family home has a negative effect on environmental awareness. This result could be considered an indicator of the influence that individuals' relatives have on students' actions (Meeusen, 2014) as well as a proof of the negative effect that age has on environmental awareness (Gifford and Nilsson, 2014). Viewed in this light, the lower environmental awareness of students who live with their families compared to those who do not —who mostly live in apartments shared with other students— could be due to living with older relatives who could influence the students' choices. In this sense, this finding supports the observation made by Zhou (2012) about the impact that the variable "embeddedness and information contagion" —which in his study is partly captured by whether or not a student lives near other students— has on the sustainable mobility choices of UCLA students when travelling to campus. On the other hand, a higher level of perceived family income negatively affects the level of awareness (Hirsh, 2010).

Table 3
MIMIC model results.

	Coefficient	Standard error	Test
I1. I am afraid when I think about environmental conditions for future generations.	1		
I2. If we continue our current style of living, we are approaching an environmental catastrophe.	1.274***	0.128	9.99
I3. In my opinion, environmental problems are greatly exaggerated by proponents of the environmental movement.	1.095***	0.122	8.97
I5. Environmental protection measures should be carried out, even if this reduces the number of jobs in the economy.	0.943***	0.105	9.01
I6. Climate change is already a reality a reality as average temperatures have increased and climate disasters are becoming more common.	0.662***	0.101	6.55
Gender	0.306***	0.058	5.27
Family home	−0.137**	0.053	2.57
Family income	−0.060***	0.017	3.57
Goodness of fit			
p-value (χ^2)	0.01355		
CFI	0.966		
RMSEA	0.042		

*, **, *** indicate significance at 10, 5 and 1% respectively.

4.2. Mode choice model results

Following a sequential estimation, after calculating, standardizing and including the latent variable, the discrete choice model was defined and estimated using Biogeme software version 3.2.10 (Bierlaire, 2020). The choice set consisted of six alternatives: by foot, bicycle, car, bus, metro/tram (jointly managed by the same operator) and train.

Based on the revealed preferences observations, a standard logit model was established, which incorporated only the modal attributes as base model. Starting from this initial model, the existence of systematic variations in preferences was analysed by incorporating the different explanatory variables, with special emphasis on those linked to environmental behavior.

The correlation in the unobserved factors of the different modes was tested through the specification of an error-component mixed logit model; however, the standard deviation of the joint random term was significant only for public transport modes (at 10 %).

Thus, the final model is an error-component mixed conditional logit given by the following utility functions, with travelling by car being the reference alternative:

$$U_{FOOT} = \alpha_{FOOT} + \beta_1 DISTANCE + \beta_2 TIME_{FOOT} + \beta_3 ENVSTU + \beta_4 RESID + \beta_5 JOB + \beta_6 AWARENESS + \beta_7 RECYCLING + \beta_8 NGO + \varepsilon_{nFOOT}$$

$$U_{BIKE} = \alpha_{BIKE} + \beta_1 DISTANCE + \beta_9 TIME_{BIKE} + \beta_{10} PHYSICAL + \beta_3 ENVSTU + \beta_4 RESID + \beta_5 JOB + \beta_6 AWARENESS + \beta_7 RECYCLING + \beta_8 NGO + \varepsilon_{nBIKE}$$

$$U_{CAR} = \beta_{11} TIME_{CAR} + \beta_{12} COSTMHI_{CAR} + \beta_{13} COSTMLI_{CAR} + \varepsilon_{nCAR}$$

$$U_{METRO} = \alpha_{METRO} + \beta_{13} DISTANCE + \beta_{14} ACCTIME_{METRO} + \beta_{15} TRATIME_{METRO} + \beta_{12} COSTMHI_{METRO} + \beta_{13} COSTMLI_{METRO} + \beta_{16} TSERV_{METRO} + \beta_{17} TRANSFER_{METRO} + \beta_5 JOB + \beta_6 AWARENESS + \beta_7 RECYCLING + \beta_8 NGO + \psi_{nPT} + \varepsilon_{nMETRO}$$

$$U_{BUS} = \alpha_{BUS} + \beta_{13} DISTANCE + \beta_{14} ACCTIME_{BUS} + \beta_{18} TRATIME_{BUS} + \beta_{12} COSTMHI_{BUS} + \beta_{13} COSTMLI_{BUS} + \beta_{16} TSERV_{BUS} + \beta_{17} TRANSFER_{BUS} + \beta_5 JOB + \beta_6 AWARENESS + \beta_7 RECYCLING + \beta_8 NGO + \psi_{nPT} + \varepsilon_{nBUS}$$

$$U_{TRAIN} = \alpha_{TRAIN} + \beta_{13} DISTANCE + \beta_{14} ACCTIME_{TRAIN} + \beta_{19} TRATIME_{TRAIN} + \beta_{12} COSTMHI_{TRAIN} + \beta_{13} COSTMLI_{TRAIN} + \beta_{16} TSERV_{TRAIN} + \beta_{17} TRANSFER_{TRAIN} + \beta_{20} FAMHOME + \beta_5 JOB + \beta_6 AWARENESS + \beta_7 RECYCLING + \beta_8 NGO + \psi_{nPT} + \varepsilon_{nTRAIN}$$

A diagram of the final model is shown in Fig. 3, while the explanation of each of the variables included is shown in Table 4 and the results obtained in Table 5.

The results of the mode-specific constants reveal a clear preference for car transport. In addition to a preference *per se* for this mode,

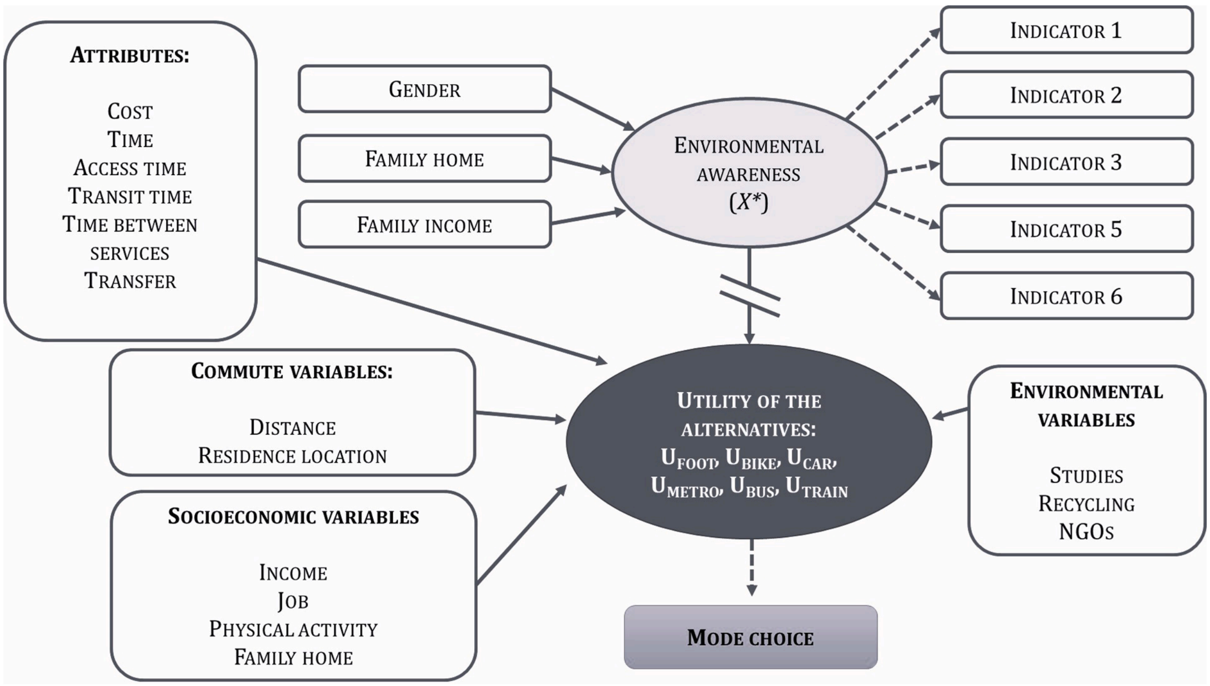

Fig. 3. Diagram of the final specification for the hybrid model. ***Source*: Own elaboration.**

Table 4
Description of the variables included in the model.

VARIABLE	DESCRIPTION	UTILITY FUNCTIONS & TYPE OF COEFFICIENT
Alternative specific constants (α)	Specific constants for each alternative that show, *ceteris paribus*, the preference or not compared to the car alternative.	All except car. Alternative specific coefficient.
Cost middle-high income (*COSTMHI*)	Variable calculated as *COST*MHI,* where: • *COST*: Monthly cost for each alternative (car, metro, bus or train) when travelling to campus. • *MHI*: Dichotomous variable that takes the value 1 if the student, on a scale from 1 (very low) to 10 (very high), perceives his/her family income as a 6 or more.	Car, bus, metro, rail. Generic coefficient.
Cost middle-low income (*COSTMLI*)	Variable calculated as *COST*MLI,* where: • *COST*: Monthly cost for each alternative (car, metro, bus or train) when travelling to campus. • *MLI:* Dichotomous variable that takes the value 1 if the student, on a scale from 1 (very low) to 10 (very high), perceives his/her family income as a 5 or lower.	Car, bus, metro, rail. Generic coefficient.
Commute total time (*TIME*)	Total time, in minutes, needed to get to campus, or to place of residence from campus.	Foot, bike, car. Alternative specific coefficient.
Access time to public transport (*ACCTIME*).	Access and egress time, in minutes, for each mode of public transport.	Metro, bus, train. Generic coefficient.
Transit time for public transport (*TRATIME*).	Transit time (inside the vehicle) in minutes for each mode of public transport.	Metro, bus, train. Alternative specific coefficient.
Time between services (*TSERV*)	Waiting time (number of minutes) between services for each mode of public transport.	Metro, bus, train. Generic coefficient.
Transfer (*TRANSFER*)	Variable that takes the value 1 when the student must transfer line/mode, and 0 otherwise.	Metro, bus, train. Generic coefficient.
Distance (*DISTANCE*)	Distance in kilometres between the student's residence during the academic course and the campus.	All except car. Alternative specific coefficient for active and public transport modes.
Environmental studies (ENVSTU)	Variable that takes the value 1 when the student's degree is associated with environmental subjects, and 0 otherwise.	Foot, bike. Generic coefficient.
Residence in the town where the campus is located (RESID)	Variable that takes the value 1 when the student lives in the same town as the campus, and 0 otherwise.	Foot, bike. Generic coefficient.
Job (*JOB*)	Variable that takes the value 1 when the student has a job, and 0 otherwise.	All except car. Generic coefficient.
Environmental awareness *(AWARENESS)*	Standardized latent variable [0–1] that measures the student's environmental awareness. The value is closer to 1 the greater the environmental awareness.	All except car. Generic coefficient.
Recycling activities (*RECYCLING*)	Variable that indicates on a scale [1–5] the frequency with which the student carries out recycling activities.	All except car. Generic coefficient.
Collaboration with environmental NGOs (NGO)	Variable that takes the value 1 when the student collaborates with organizations or groups working to protect nature and the environment, and 0 otherwise.	All except car. Generic coefficient.
Frequency of physical exercise (PHYSICAL)	Variable that indicates on a scale [0–8] the weekly frequency of physical exercise, from never (0) to every day of the week (8).	Bike
Family home (*FAMHOM*)	Variable that takes the value 1 if the student lives with his/her family during the academic year, and 0 otherwise.	Rail

this result could also be capturing the comparative advantage that the car usually has in aspects that could not be explicitly incorporated into the model such as comfort, reliability or flexibility (Thorhauge et al., 2020).

The preference for the private vehicle can however be modified by the different socioeconomic factors considered. Thus, the effect of the alternative specific constants of the bicycle and train alternatives can decrease depending on the frequency with which the student exercises —the physical effort associated with travelling by bike is one of the main barriers to this transport mode choice— and whether the student resides in the family home, respectively. This last result, given that there is a greater proportion of family homes located in the periphery and in suburban areas, leads to an analysis of the relationship between transport mode choice and housing location choice (Zhou, 2014, 2012).

The aforementioned hypothesis of greater preference for the private vehicle due to its flexibility is reinforced by the negative sign obtained for the coefficient of the dichotomous variable that indicates whether the student combines his/her studies with a job. Those individuals who work in addition to studying show a greater preference for the car as a transport mode. A similar conclusion was reached in studies that jointly analyse students and university employees, since the results show that the latter group is more likely to

Table 5
Transport mode choice model results.

COEFFICIENT	VALUE	T-TEST
α_{FOOT}	−3.72	−1.71*
α_{BIKE}	−9.87	−4.36***
α_{METRO}	−5.44	−3.46***
α_{BUS}	−4.63	−2.86***
α_{TRAIN}	−12	−5.77***
COSTMHI	−0.0115	−1.73*
COSTMLI	−0.0267	−2.78***
$\mathrm{TIME}_{\mathrm{FOOT}}$	−0.102	−3.43***
$\mathrm{TIME}_{\mathrm{BIKE}}$	0.234	3.14***
$\mathrm{TIME}_{\mathrm{CAR}}$	−0.355	−4.1***
ACCTIME	−0.2	−4.97***
$\mathrm{TRATIME}_{\mathrm{METRO}}$	−0.0426	−1.94*
$\mathrm{TRATIME}_{\mathrm{BUS}}$	−0.088	−3.3***
$\mathrm{TRATIME}_{\mathrm{TRAIN}}$	−0.0934	−1.68*
TSERV	−0.0365	−2.72***
TRANSFER	−1.03	−2.81***
DISTANCEACT	−2.06	−3.61***
DISTANCEPT	−0.192	−2.74***
ENVSTU	7.55	2.53**
RESID	3.08	2.08**
JOB	−1.39	−2.41**
AWARENESS	−0.216	−0.13
RECYCLING	0.886	4.24***
NGO	2.62	2.85***
PHYSICAL	0.203	1.99**
FAMHOM	9.05	5.97***
PT_DESV	−1.42	−1.65*
*, **, *** indicate significance at 10, 5 and 1 % respectively.		
Observations = 499 $L(0) = -474.9188$ $L(\beta) = -239.2175$	$\rho^2 = 0.496$ $\rho^2 adj = 0.439$	AIC = 532.435 BIC = 646.1754

choose the car alternative (Gutiérrez-Gallego and Pérez-Pintor, 2019; Hamad et al., 2021).

The preference for the car increases for greater distances, although the impact is not homogeneous for all modes. As expected, the utility of active modes shows a greater proportional reduction over longer distances than the utility of public transport modes. However, the negative effect of distance on the utility of active modes can be mitigated if the student lives in the town where the campus is located. This variable was introduced to approximate the relative quality of the built environment and, more specifically, to approximate the quality of the infrastructure to promote active travel. It is expected that the quality of the infrastructure installed to facilitate active transport will be lower between towns than within the same town. The positive sign of the coefficient is in line with the empirical evidence in this regard (Rodríguez and Joo, 2004; Sottile et al., 2022; Vale et al., 2018; Whalen et al., 2013).

The cost coefficient, introduced as an interaction with the perceived level of family income, shows a negative effect of this attribute (Danaf et al., 2014; Rodríguez and Joo, 2004) on the utility; as expected students who perceive their family as having a medium/low income show greater sensitivity to cost.

Regarding time, in the case of walking and car modes the sign obtained is, as expected, negative. However, the coefficient for the bicycle is positive, a result previously reported in the literature (Páez and Whalen, 2010; Whalen et al., 2013), which implies that the utility of biking increases with increasing time and could be explained by the enjoyment students may feel when exercising while traveling. In Whalen et al. (2013) the logarithmic transformation of time allowed for establishing a positive but decreasing impact of transit time. In our case, the decreasing impact of time was analyzed through a second-degree polynomial specification of cycling time; however, this hypothesis could not be confirmed as we obtained a non-significant coefficient for time squared. The positive but non-decreasing impact of cycling time here obtained could partially be explained by both, the fact that commutes in our sample do not involve excessive times (average commuting time is 12 min) and the fact that very short commutes can also be perceived as a barrier to bike use. Indeed, when students who included cycling in their choice set but didn't use it were asked about the main reasons for not cycling to campus, very short distances were the most frequently cited barrier.

For public transport, the coefficient for access time is notably higher than that for transit time for all alternatives, a similar result to those reported by Mehdizadeh et al. (2019) and Zhou (2014). The different micro-mobility options, both electric and shared —the use of which is not yet well-established in the city of Valencia— could facilitate a reduction in access and egress times, and thus the relative competitiveness of public transport with respect to the car.

Finally, as regards the variables related to environmental awareness and behavior, the results show that, in this case study, awareness *per se* —the latent variable— does not play a significant role in the choice. Models were also estimated with the coefficient of the latent variable specified as mode-specific for active modes and/or public transport, and similarly, no statistically significant coefficients were obtained. These results are partially supported by those of a study conducted by Mehdizadeh et al. (2019) in which the authors identified that, from a more psychological perspective, environmental awareness could influence the choice of more sustainable modes during summer but not during winter, or the study conducted by Sobrino and Arce (2021) in which environmental awareness was not among the top criteria for choosing the mode of transport in students' daily transport choice. Likewise, in studies not focused on university students, Fallah Zavareh et al. (2020) concluded that environmental awareness does not play a very relevant role in active modes choice, while Ramos et al. (2020) pointed out that the car's environmental impact is not taken into account except when travelling to work.

Given the non-significance of the latent variable, it was especially relevant to assess whether or not university students' transport mode choice is connected to environmental behaviors. To this end, the variables related to pro-environmental actions —behaviors— were included in the model. Both collaborating with NGOs related to environmental protection (NGO variable) and recycling (RECYCLING variable) appear to show a positive correlation with the probability of choosing alternative modes. It should be noted that during the model specification process, the variable associated with energy and water savings at home was also incorporated, although their coefficients were not statistically significant. Thus, while the frequency with which a pro-environmental action such as recycling —which requires an altruistic effort— is positively correlated to the preference for sustainable modes, the frequency of actions related to saving water or energy —which a priori may require less effort and are also associated with a direct individual benefit— does not. A positive effect was also identified for students taking courses linked to the environment (ENVSTUD variable) on the choice of active modes —those with the least, or no, environmental impact.

The results confirm the independence previously observed for the general population between individuals' level of awareness and their actions to protect the environment; in other words, the dissociation between pro-environmental attitudes and behaviors (Bell et al., 2008; Sabourin and Lamarche, 2001). Duque et al. (2014) confirmed this dissociation in the university environment, concluding that those individuals with the greatest probability of reporting pro-environmental actions are also those with the greatest probability of travelling longer distances in larger vehicles. Szasz (2007) argued that high levels of awareness are not necessarily linked to more sustainable choices since individuals may perceive that the small actions they already carry out are enough to protect the environment.

4.3. Policy actions

The results of the final model were used to estimate the effect that different actions would have on the shares of the different modes that make up the choice set. Table 6 shows the percentage change in the modal shares compared to the baseline case (current scenario) under different changes in levels of service or behaviors. These figures were obtained using the sample enumeration method (Ben-Akiva and Lerman, 1985). This information will allow us to specifically evaluate the most effective measures to reduce car use as well as minimizing the likelihood of commuters shifting from active transportation modes to public transport, particularly in scenarios where the quality of the latter improves.

Indeed, although the aim of improving the level of service of the public transport alternatives is to encourage a shift from private vehicles to public transport, it is worth studying whether these improvements may in fact lead to a reduction in the use of active modes in favour of public transport. Hence, in addition to the long-standing debate focused on transferring users of private vehicles to public transport, there is a need for debate about the effect that the promotion of public transport could have on the share of active modes, specifically cycling.

In this respect, the most effective actions relating the level of service of the different modes would be those that affect the transit time of the car. Specifically, increasing the total time by car by 10 min (see Fig. 4) could reduce its mode share by 12 percentage points, which would mainly lead to an increase in the use of public transport: the probability of choosing public transport would increase by 5.5 percentage points for the metro, 3.4 for the bus and 1.2 for the train. To a lesser extent, it would also lead to an increase in the use of active modes: 0.8 percentage points for biking and 1.5 for walking. Policy actions that would lead to an increase in total time could include reducing the number of lanes or the imposition of traffic restrictions (Danaf et al., 2014; Guzman and Diaz, 2005; Nordfjærn et al., 2019) or, the most common measure, increasing parking times by moving the parking spots further away or even reducing the parking space in the campus surroundings (Cattaneo et al., 2018; Miralles-Guasch and Domene, 2010; Rotaris and Danielis, 2014). In the specific case of the city of Valencia, this action could be carried out both by the universities themselves, who are responsible for and manage their campus parking, as well as by local authorities, who are responsible for and manage the parking in the surrounding areas of the campus.

While the elimination of transfers and reduction in the time needed for public transport modes would have the desired effect of reducing car use, they would nevertheless lead to a loss of bicycle share and to a proportionally greater intra-public transport competition.

Regarding the elimination of transfers, it should be noted that the results obtained only allow us to assess the potential effect that their complete elimination would have, which would undoubtedly be impossible to implement. A complete elimination of transfers would lead to a car share reduction of 1.74 percentage points, which is a decrease compared to its base share of 7.9 %, but this is the maximum reduction that could be achieved in the use of the private vehicle. The implementation of measures to facilitate these transfers is more realistic. For example, this result supports the introduction of the SUMA system in Valencia in 2022, which levelled the fares of different public transport modes and allows transfers between them at no additional cost during a period of 60 min. Another measure that, while it may not directly impact the need to transfer, could perhaps act as a facilitator, would be the integration of real-time information for all public transportation alternatives into a single system. While such a measure exists in many cities, it is currently not available in Valencia. The need to check different apps or the limited reliability of more generic ones, due to the lack of real-time information, can lead to additional waiting times that could be reduced or to the selection of a less efficient route (Casquero et al., 2022).

The SUMA system also introduced a reduction in rates of between 11 and 55 %, although according to our results, modifying costs does not seem to be the most appropriate measure to modify the mobility patterns of students in their trips to campus.

Table 6
Variations in transport alternatives shares with respect to the base scenario, percentage.

	WALK	BIKE	CAR	METRO	BUS	TRAIN
BASE CASE	26.48%	9.68%	21.98%	21.94%	15.43%	4.49%
CAR COST +1%	0.01%	0.01%	-0.18%	0.08%	0.07%	0.15%
CAR TIME +1 MINUTE	0.57%	0.81%	-5.58%	2.49%	2.17%	2.60%
WALKING TIME -1 MINUTE	1.91%	-2.95%	-0.21%	-0.43%	-0.51%	0.00%
TRANSIT COST -1%	-0.02%	-0.09%	-0.06%	0.07%	0.06%	0.09%
TRANSIT: TIME BETWEEN SERVICES -1 MINUTE	-0.23%	-0.78%	-0.47%	0.60%	0.64%	0.26%
TRANSIT: ACCESS & EGRESS TIME -1 MINUTE	-1.31%	-4.26%	-2.58%	3.29%	3.50%	1.45%
METRO: IVT -1 MINUTE	-0.14%	-0.50%	-0.30%	1.13%	-0.58%	-0.10%
BUS: IVT -1 MINUTE	-0.26%	-0.86%	-0.39%	-0.84%	2.92%	-0.63%
TRAIN: IVT -1 MINUTE	0.01%	0.00%	-0.14%	-0.05%	-0.20%	1.57%
TRANSIT: DIRECT SERVICE	-0.32%	-3.62%	-7.90%	8.96%	-0.98%	7.90%
RECYCLING	0.91%	1.08%	-8.27%	3.63%	3.08%	4.48%
PHYSICAL ACTIVITY: +1 DAY	-2.06%	10.21%	-0.19%	-0.99%	-1.16%	0.00%

Source: Own elaboration.

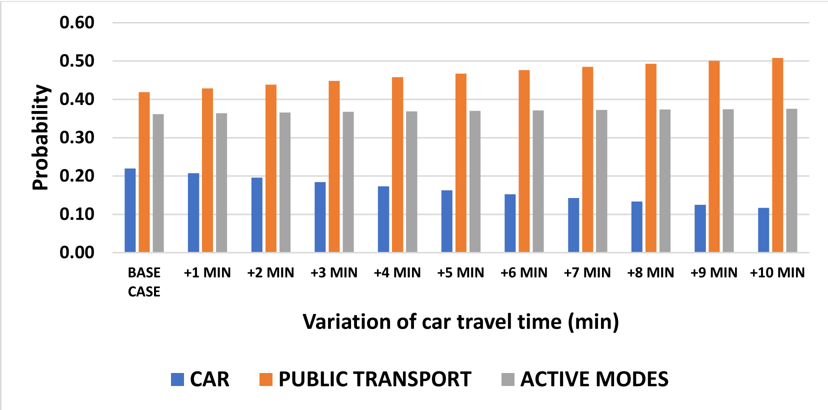

Fig. 4. Estimated probabilities of traveling by different modes in response to increases in car transit time. ***Source*: Own elaboration.**

Although it has not been directly addressed in the scenarios presented, the implementation of measures that could encourage bicycle use and reduce the preference gap in favor of cars could also be considered. Currently, the integration of bicycles with public transportation in Valencia is limited; for example, bicycles can only be transported on the metro on surface-level routes, significantly reducing possible routes, and in the case of buses, only folding bicycles are allowed. Facilitating access or designating specific spaces to bring bicycles on board is also an action yet to be implemented. Additionally, another interesting measure could be extending the time availability of the public shared bicycle system, which is currently limited to 30 min. This limitation makes it difficult for students who live further away to choose this option (need to find a new station to switch bicycles, interruption of the journey and increased travel time).

The analysis of different possible policy actions also incorporates the effect of the frequency with which the student exercises and the habit of recycling. Actions in the area of sustainable mobility usually seek to divert trips from the most polluting modes to the most sustainable ones through actions that mainly affect their level of service in terms of different attributes such as cost, time, improvement of infrastructures, improvements in frequencies, changes in the public transport networks, etc. Conversely, actions directly focused on users are much less frequently employed, such as those that encourage more sustainable individual actions since there does seem to be a clear correlation between environmentally friendly actions. Efforts to embed sustainable behaviors —promotional campaigns or reward programs— could help consolidate other sustainable behaviors, such as opting for transportation modes that have a reduced environmental footprint.

5. Conclusions

Against the backdrop of climate change and increasing environmental awareness, the city of Valencia, Spain, serves as an ideal setting for investigating university students' choices of transport mode, especially given its characteristic flat terrain, year-round favourable weather conditions and extensive public transport network. To that end, we developed a hybrid discrete choice model to identify the determinants of transport mode choice, focusing on the role that environmental awareness and behaviors play in this choice, and to identify the best possible policy actions. Since environmental awareness is not directly observable, it was included in this model as a latent variable constructed from several statements (indicators) that capture this awareness.

Results show that, despite there being a preference for car use, the use of active modes can be enhanced by promoting greater physical activity (Rissel et al., 2013), improving infrastructures, and particularly by reducing travel distances. The latter finding has prompted various authors to call for more student housing to be built close to campuses (Lavery et al., 2013; Shannon et al., 2006; Vale et al., 2018; Zhou, 2014) or the creation of so-called university cities (Chen, 2012). There is a more direct competition between car and public transport alternatives since they are usually used over longer distances. Again, increasing the probability of choosing public transport can be achieved by improvements, especially in access times, eliminating the need for transfers, and also, although less effective, with the reduction of transit times or costs. This latter result is especially relevant since one of the most commonly implemented policy actions is a reduction in costs to facilitate access to public transport; however, other actions could lead to better results.

As regards environmental awareness, although we might expect to find that users with a higher level of environmental awareness would choose more sustainable modes, this variable does not appear to be significant. An explanation for this is the disocciation between awareness and action on environmental issues previously found in the literature (Kennedy et al., 2009; Kollmuss and Agyeman, 2002; Marcell et al., 2004). The results obtained here suggest that the choice of a sustainable mode of transport is linked to environmentally sustainable habits acquired; that is, students who engage in recycling, collaborate with NGOs or are in environmental related degrees, seem to be more likely to choose the more sustainable transport alternatives. Therefore, what is really relevant for establishing sustainable mobility patterns is to what extent the student is showing, through such altruistic pro-environmental behaviors, his/her effective commitment to the preservation of the environment. In this way, this research allows us to demonstrate that a value-action gap exists in the choice of transportation mode among university students.

This research opens potential future lines of study. Even though the sample comes from public universities, which account for more than 75 % of university students in the city, it would be worth assessing whether the role of environmental awareness and pro-environmental actions varies for students from private universities, not only due to income but also considering the social context. Also, given the implementation of measures within the SUMA program, such as integrated fare systems and improved transfer options, it would be of interest to analyze pre- and post-implementation data to assess the impact this program has had on the transportation choices of university students. It would also be advisable to explore the correlation between the various pro-environmental actions taken by university students. This could be done by following studies like Shafiei and Maleksaeidi (2020), which evaluate the relationship between attitudes, behaviors, costs, and rewards. Alternatively, other modeling frameworks, such as structural equations, as in Jamal and Paez (2023), could be used to better model the relationship between these behaviors.

The study presents certain limitations that should be considered. Among them, since this is a case study specific to the city of Valencia, the generalization of the results should be approached with caution and would primarily apply to cities sharing characteristics with Valencia, such as an extensive public transport network, a supportive environment for active transportation modes, and a large university population. Additionally, it is important to note that the relationship between the various pro-environmental actions is not yet fully defined, and the potential causal links between them, as mentioned, require further research. Nevertheless, despite these limitations, the results of this study can be very useful for preliminary testing of future public acceptance of more sustainable urban transport solutions.

CRediT authorship contribution statement

Barbara Vazquez-Paja: Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **María Feo-Valero:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Formal analysis. **Salvador del Saz-Salazar:** Writing – review & editing, Visualization, Validation, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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