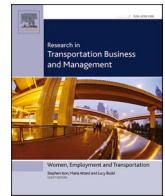




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Who is more willing to use a smartphone app to promote sustainable travel behavior?

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ABSTRACT

In the last decade, there has been growing interest in Voluntary Travel Behavior Change (VTBC) programs that use smartphone applications to encourage people to shift from car use to more sustainable transportation modes. However, most of these programs have used small and distorted sample sizes, making it unclear who are the individuals who choose to download and use such apps. To address this gap, in the current study we investigate which objective and subjective factors could influence individuals' intention to use a VTBC application designed to promote sustainable mobility, while also examining the interplay between this intention and current travel habits. To analyze these relationships, we developed a joint Integrated Choice and Latent Variable (ICLV) model that simultaneously considers two choice dimensions: (1) current commuting mode choice, and (2) intention to adopt the VTBC application. Our analysis uses data from 3044 commuters who were invited to take part to a VTBC program in the Cagliari metropolitan area (Italy). At the aggregate level, 44.1 % of respondents expressed interest in using the VTBC application. The modeling results reveal that individuals with graduate education, monthly incomes below €2000, and bicycle ownership demonstrate higher likelihood of app adoption. Among psychological factors, *Environmental Concern* and *Attitude toward Sustainable Mobility* positively influence the intention to use the application. As far as the interaction with mode choice is concerned, public transit users show stronger intention to adopt the application. Notably, some of the variables influencing app adoption intention differ from those affecting commuting mode choice, suggesting these represent distinct behavioral processes. These findings have important policy implications, emphasizing the need to carefully consider the promotion of such to engage as many people as possible. Additionally, extra caution is required when interpreting the results of these programs and their generalizability to the entire population, due to the self-selection of participants.

1. Introduction

To reduce the negative impacts generated by the intensive usage of private vehicles, various strategies and measures have been implemented over time. These include discouraging car use through legislative measures, such as the introduction of congestion pricing schemes, or enhancing the attractiveness of environmentally friendly modes of transport, such as public transport and active mobility. Measures aimed at increasing the attractiveness of sustainable transportation alternatives include improving public transport's level of service characteristics (De Oña, 2020; Redman et al., 2013), introducing new walking and cycling paths (Mitra et al., 2021), and implementing informative strategies (Piras et al., 2022; Richter et al., 2011).

In particular, informative strategies, often referred to as Voluntary Travel Behavior Change (VTBC) programs or Mobility Management programs, use various types of information and communication to enhance individuals' knowledge and awareness, aiming to influence their attitudes and encourage the adoption of more sustainable travel behaviors (Sanjust di Teulada et al., 2015). An appealing tool for improving the effectiveness of VTBC programs is the use of smartphone applications (Dastjerdi et al., 2019; Sottile et al., 2021). Indeed, these applications allow for the implementation of VTBC programs on a population scale at reduced costs. Beyond that, they can be more powerful than traditional informative campaigns, providing real-time information to a large number of participants, proposing them personalized and flexible transport solutions as alternatives to private cars

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(Sottile et al., 2021), and utilizing persuasive technology techniques (Fogg, 2003).

Despite the presence of different studies indicating the benefits of employing mobile technology, the generalizability of the results of much published research on this topic is problematic. In fact, the vast majority of VTBC programs implemented through smartphone applications have relied on convenient samples, often with a low number of participants (Sottile et al., 2021). Such samples are not necessarily representative of the whole population, and it is unknown whether the measures, if deployed on a large scale, will have the same impact. Indeed, the effectiveness of a VTBC program delivered through a smartphone application depend on users' levels of engagement and acceptance of the app (Andersson et al., 2018; Ettema, 2018).

Next, as indicated in studies on ecological behavior (Hoffmann et al., 2022; Li and Liu, 2024) and health and fitness (Pontin et al., 2021; Yeoh et al., 2024), these kinds of app-based programs are prone to self-selection bias, as they often attract only specific categories of individuals who have additional motivation to participate. One group consists of people who, for various reasons, are already in the process of changing their lifestyle and travel behavior (Sanjust di Teulada and Meloni, 2016; Sunio et al., 2018) and only need a small trigger or support to complete this process. For instance, individuals with strong environmental concern, due to their sensitivity to sustainability issues, are often in a stage of reflecting on their current behavior and recognizing the benefits of change and may be attracted to an app that promises to support them in completing this transition (Friman et al., 2017; Sanjust di Teulada and Meloni, 2016). Another group includes individuals who already use sustainable transportation alternatives, particularly when the program offers monetary incentives for sustainable travel. For these participants, little additional effort is required to modify their travel behavior; instead, they gain extra motivation through the opportunity to win monetary prizes, which makes participation more appealing compared to car users. Indeed, several studies (dos Reis et al., 2022; Liu et al., 2025; Xiao et al., 2024) have shown that incentives promoting sustainable mobility are more effective among individuals who already practice sustainable travel habits. Furthermore, the analysis is complicated by the fact that these two groups often overlap (Bouscasse et al., 2018; Vázquez-Paja et al., 2024), making it difficult to disentangle the specific motivations driving participation.

Hence, it is crucial to analyze which factors, both objective and subjective, influence the use of this new technology and which barriers hinder its adoption (Dickinson et al., 2015). However, to date, only a few studies have explored this issue (Dastjerdi et al., 2019; Piras et al., 2025; Yen et al., 2023), and none have shed light on the relationship between intentions to use VTBC apps and users' current transportation modes.

In this paper we examine which categories of individuals are more inclined to use a VTBC smartphone application designed to promote sustainable mobility. Specifically, our objectives are twofold: (1) to investigate whether individuals' intention to use a VTBC application varies according to their sociodemographic and psychosocial characteristics, and (2) to assess whether there is a relationship between this intention and the choice to commute using sustainable modes of transport.

The dataset used in this study was collected between 2019 and 2020 through an online survey, conducted as part of a smartphone-based VTBC program implemented in the metropolitan area of Cagliari, Italy. The data are analyzed by specifying and estimating a joint Integrated Choice and Latent Variable (ICLV) model. The model considers two choice dimensions: commuting mode choice and the intention to use the VTBC application. The development of the ICLV model enables a comprehensive understanding of the factors, both objective and subjective, influencing both decision processes and whether they differ. Furthermore, it allows for the assessment of the impact of variables associated with the choice of sustainable commuting mode on the utility derived from participating in the app-based VTBC initiative, while avoiding its overestimation. By considering the two different choice

dimensions and their relationship, the present paper extends the analysis conducted in Piras et al. (2025), which used data collected from the same survey. However, that earlier study focused solely on individuals who commuted to work by driving a car and their intention to use the VTBC app.

The rest of the paper is organized as follows. Section 2 reviews past research on the willingness to use travel apps and to participate in VTBC programs. Section 3 describes the data collection process, while Section 4 presents the modeling approach. Section 5 discusses descriptive analysis and model results. Policy implications are drawn in Section 6, and Section 7 concludes the paper.

2. Literature review

Different studies have investigated the willingness to use smartphone applications designed for transportation purposes. We can distinguish between three different types of applications:

- Smartphone applications that allow planning, reservation, and payment of transportation services
- Smartphone applications for data collection
- Smartphone applications aimed at encouraging changes in travel behavior through information provision and gamification.

A substantial body of literature has examined the willingness to use the first type of application, driven by the growing presence of digital ticketing systems, travel planners, and transportation services. Studies on generic travel planning and ticketing applications include Susanto et al. (2020), Altay and Okumus (2022), Ferreira et al. (2022), Rizki et al. (2024), Hasselwander (2025) and De Menezes Amorim and De Abreu e Silva (2025). Research focused specifically on MaaS apps includes Schikofsky et al. (2020) and Meloni et al. (2024), while studies on ride-hailing and shared mobility apps include Nikiforiadis et al. (2019), Ratan et al. (2021), Elnadi and Gheith (2022), and Park and Le (2023).

In contrast, the propensity to use applications designed for travel survey data collection have been less extensively investigated, even though various studies confirm that such applications are among the most accurate and reliable methods for gathering data (Harrison et al., 2020; Hesjevoll et al., 2021). Assemi et al. (2018) employed a post-experience survey to evaluate user perceptions and participation intentions following a two-day trial of a survey app in Australia. Verzosa et al. (2021) conducted a survey across 24 countries to assess the propensity to participate in different types of surveys, including those using smartphone apps that record location data. Bürbaumer et al. (2024) explored the motivations for participating in a smartphone-based data collection program in Austria. More recently, Greaves et al. (2025) investigated the factors influencing participant retention and engagement with a travel information app, as part of a long-term longitudinal study in Australia.

Over the past decade, there has been increasing interest in the idea that, in addition to collecting data, mobile applications can also inform users and incorporate gamification elements to encourage changes in travel behavior. Some scholars have proposed such applications as effective tools for implementing Voluntary Travel Behavior Change (VTBC) programs and enhancing their impact. Notable examples include Quantified Traveler (Jariyasunant et al., 2015), Traffico₂ (Di Dio et al., 2018), OPTIMUM (Tsirimpa et al., 2019), IPET (Sottile et al., 2021), and Bellidea (Cellina et al., 2023). However, even for such applications, the mechanisms that drive user adoption remain unclear, and only a few studies have investigated this issue. Dastjerdi et al. (2019) examined the motivations for using a new real-time, multimodal travel application in Copenhagen, conceptualized as an Advanced Traveler Information System (ATIS) aimed at supporting digital mobility management. In contrast, Yen et al. (2023) offered a more targeted investigation, exploring which user perceptions and attitudes influence participation in a public transport gamification scheme delivered via a mobile app in

Australia.

When assessing factors that influence individuals' willingness to use new technologies three main psychological theories are commonly referenced: the Theory of Planned Behavior (TPB), the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT). The TPB, developed by Ajzen (1991), assumes that attitudes, subjective norms, and perceived behavioral control influence intention, which in turn shapes behavior. TAM (Davis, 1989) also centers on intention as a predictor of behavior. In this framework, intention is influenced by perceived usefulness and perceived ease of use, which together shape attitudes toward technology. UTAUT (Venkatesh et al., 2003) extends TAM by proposing that the factors influencing the intention to adopt a new technology include not only utilitarian constructs, such as perceived usefulness and ease of use, but also hedonic variables. Most of the studies investigating the intention to use a smartphone app designed for transportation purposes followed TAM and its extensions (Altay and Okumuş, 2022; Assemi et al., 2018; Elnadi and Gheith, 2022; Ferreira et al., 2022; Meloni et al., 2024; Ratan et al., 2021; Schikofsky et al., 2020), others adopted UTAUT (Greaves et al., 2025; Hasselwander, 2025).

Nevertheless, in the context of VTBC programs, different psychological models may be more appropriate. For example, Sanjust di Teulada and Meloni (2016) recommend using the Transtheoretical Model, suggesting that individuals in the precontemplation stage are more likely to participate in such programs. They also propose TPB as suitable, particularly when targeting individuals who already hold positive attitudes toward sustainable mobility. Taniguchi et al. (2014) and Skarin et al. (2019), who investigate motives for participating in traditional VTBC programs, did not explicitly apply a psychological theory in their work. Instead, they asked participants to choose among different factors for participation, including health reasons, environmental concerns, and instrumental motivations. Due to this unique characteristic of VTBC programs, the two studies examining the willingness to use a VTBC app adopt a slightly different psychological framework from those exploring factors that influence the use of other types of transportation apps. Yen et al. (2023) applied a hybrid framework combining elements of both TAM and TPB. Dastjerdi et al. (2019) investigated whether satisfying functional and psychological user needs, along with environmental attitudes, privacy concerns, and perceived difficulties in using the app, influences the intention to use a mobility management app.

Overall, the studies mentioned above provide insights into which individuals are more likely to be attracted to participate in such programs and to download and use these apps, as well as what motivates or discourages their use. App-based programs and surveys tend to appeal more to younger individuals (De Menezes Amorim and De Abreu e Silva, 2025; Verzosa et al., 2021). Regarding gender, the evidence remains inconclusive, although some studies (De Menezes Amorim and De Abreu e Silva, 2025; Verzosa et al., 2021) suggest that males are more likely to express an intention to use transport applications. Intrinsic motivations, particularly the perceived ease of use and perceived usefulness of the application, have been shown to be critical factors influencing adoption (Altay and Okumuş, 2022; Assemi et al., 2018; Schikofsky et al., 2020; Yen et al., 2023). Technophilia and familiarity with mobile applications also appear to influence users' intentions (De Menezes Amorim and De Abreu e Silva, 2025; Hasselwander, 2025). In contrast, privacy concerns have generally been found to negatively affect the intention to use travel-related apps (Assemi et al., 2018; Dastjerdi et al., 2019; Verzosa et al., 2021; Yen et al., 2023). Interestingly, two studies reported a positive link between environmental concern and the willingness to use travel applications (Dastjerdi et al., 2019; Greaves et al., 2025). In addition to intrinsic motivations, extrinsic factors, such as rewards and incentives, can also encourage the adoption of travel apps (dos Reis et al., 2022; Verzosa et al., 2021). For instance, Verzosa et al. (2018) found that rewards were the most important feature motivating users to engage with an application designed for data collection. As far as the relationship between mode of transportation and app usage is

concerned, the research conducted by De Menezes Amorim and De Abreu e Silva (2025) showed that public transport users were more apt to use a new real-time multimodal mobility application.

Until now, we have described the factors that can influence the intention to use a smartphone application for transportation. However, when dealing with smartphone applications aimed at promoting travel behavior change, it is also important to consider both the number of individuals participating in the program and the overall participation rate. This is because the success of such measures depends on how many people take part and how widely the application is adopted by the population (Ettema, 2018). So far, most of all conducted experiments have involved relatively small samples, whose number of participants is smaller than 200 (Piras et al., 2025). Hence, even when a significant portion of participants changes their travel behavior, the overall impact remains limited. Furthermore, most studies do not report participation rates, and more detailed information is usually available only for applications used in data collection. In such cases, reported participation rates generally range between 20 % and 30 % (Verzosa et al., 2021).

The review above highlights that most studies in the field of transportation applications have primarily focused on the motivations and barriers influencing the adoption of apps that provide access to novel transportation services and ticketing systems, rather than those designed to promote sustainable mobility. Moreover, much of the existing research has been limited to assessing perceived ease of use, usefulness, and familiarity with smartphone applications, while neglecting environmental considerations as well as attitudes and perceptions toward sustainable mobility, which could play a key role in driving the adoption of apps aimed at fostering sustainable transportation adoption. A further limitation of prior research is its insufficient examination of the relationship between individuals' existing travel behaviors and their intention to use VTBC applications, a gap that may compromise the validity of VTBC program evaluations.

3. Data collection methodology

3.1. The Voluntary Travel Behavior Change program

Data used in the present study were collected as part of a Voluntary Travel Behavior Change (VTBC) program conducted in the municipality of Cagliari, a mid-sized city in Italy. The program was funded by the Italian Ministry of the Environment under the National Experimental Program for Sustainable Mobility,¹ and developed by the Municipality of Cagliari in collaboration with the University of Cagliari. The aim of the program was to promote sustainable mobility by encouraging and motivating citizens, through communication, personalized information and monetary incentives, to voluntarily change their travel habits in the city by choosing sustainable alternatives to private car use.

The program was structured in several phases, the core of which was the development and release of a smartphone application, named *Svoltiamo*, designed to automate the various stages of the VTBC process and to enable large-scale implementation. Through a GPS logger, the app allows users to record and track their daily journeys, capturing data on activities and trips throughout the day. This information is then automatically processed to generate a Personalized Travel Plan, providing tailored sustainable mobility solutions along with feedback on the benefits of adopting sustainable transport modes in terms of time and cost savings, reduced CO₂ emissions, and additional calories burned. In addition, users could earn virtual points by choosing sustainable transport options. These points, accumulated exclusively for home-to-work trips, gave participants the opportunity to win monetary prizes to be used for the purchase of a bicycle or a public transport pass. The total value of the monetary prizes was €110,000.

¹ <https://www.mase.gov.it/portale/programma-sperimentale-nazionale-di-mobilit%C3%A0-sostenibile-casa-scuola-e-casa-lavoro>

3.2. Recruitment process

To collect data, we followed the steps outlined in Fig. 1. In the first step (from November 2019 to January 2020), we contacted potential participants in the VTBC program and invited them to complete a questionnaire. The survey gathered information about their commuting trips, socio-economic characteristics, and psycho-social attitudes toward sustainable mobility. Potential participants were reached through a promotional campaign conducted via multiple channels, including TV, radio, posters, postcards, social media platforms, and mailing lists from the Public Administration office of Cagliari as well as from the University of Cagliari’s staff and student body.

At the end of the first phase, the number of complete questionnaires turned out to be 4616.

In the second phase (February 2020), we contacted by email all individuals who had completed the first-wave survey and were identified as part of the study’s target group, namely those who reported having access to a car for commuting trips (3044 individuals). We asked them about their willingness to use the smartphone application for at least two weeks. In the email, we explained how to use the app and how participation in the program could lead to winning prizes. By the end of this phase, 1343 individuals (44.1 %) expressed interest in participating in the program and using the VTBC application. Individuals who did not respond to the invitation were considered uninterested in participating.

3.3. Questionnaire: Psycho-social variables

The formulation of the psycho-social items to be included in the questionnaire involved different phases.

In the initial phase, we conducted a comprehensive literature review of studies investigating psycho-social factors influencing the adoption of sustainable mobility. Subsequently, we selected the most relevant items tailored to the context and objectives of the VTBC program. The items corresponded to the following psychological constructs: *Social Norm*, *Emotions*, *Environmental Concern*, *Place Identity*, *Attitude toward Sustainable Mobility*, and *Perceived Behavioral Control* (details on the sources used to identify the items can be found in Piras et al., 2025). Prior to the survey, a small sample of workers and students participated in filling out the questionnaire to assess the clarity of the language used in the questions.

All the items were expressed employing a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). We would like to highlight here that the decision to only include in the questionnaire psychosocial

constructs related to sustainable mobility, rather than other factors influencing the intention to use a smartphone application (such as a technophile attitude or perceived ease of using the app), was made given the primary focus of the VTBC program, namely understanding facilitators and barriers to the adoption of sustainable means of transport for the home-to work/study trips.

3.4. Sample characteristics

Table 1 summarizes the characteristics of the 3044 individuals invited to participate in the second phase of the VTBC program. The gender distribution is nearly balanced, with 49.0 % men and 51.0 % women. The majority of participants fall within two age groups: 41–60 years (46.5 %) and 18–30 years (31.3 %). The average age is 40.32 years. More than half of the sample (53.1 %) reported having at least a bachelor’s degree. In terms of occupation, 71.9 % of respondents are employed, while 28.1 % are students. The average household size is 2.97 members, and 34.1 % of respondents have at least one child. Regarding mobility resources, households own an average of 1.84 cars, and 53.6 % of respondents have access to a bicycle. The sample reported the following monthly income levels: 31.1 % earn less than €1000, 49.8 % earn between €1001 and €2000, 11.4 % earn between €2001 and €3000, and 7.8 % earn more than €3000.

Regarding the commuting mode choice, the majority of the sample uses a private vehicle (64.8 %). 25.5 % of participants go to work or university by transit, whereas 9.7 % declared to use the active mobility for commuting. The average commuting distance is 9.38 km. As indicated before, 44.1 % of individuals contacted (1343 individuals) agreed to participate in the program and use the VTBC app.

Compared to the characteristics of the active population of Cagliari, our sample mainly differs in age distribution (18–30 years: 13.1 % in Cagliari vs. 31.3 % in our sample; Age > 60: 22.8 % in Cagliari; 6.3 % in our sample) and modal share, showing a lower proportion of car users (77.0 % in Cagliari vs. 64.8 % in our sample) and a higher share of public transport users (9.7 % in Cagliari vs. 25.5 % in our sample). This difference in modal share may be explained by the fact that our sample primarily includes people who work and study in the city center of Cagliari, which is well served by public transport.

4. Conceptual model and modeling approach

Fig. 2 displays the conceptual framework of the model. Ovals represent latent variables, while rectangles represent the endogenous

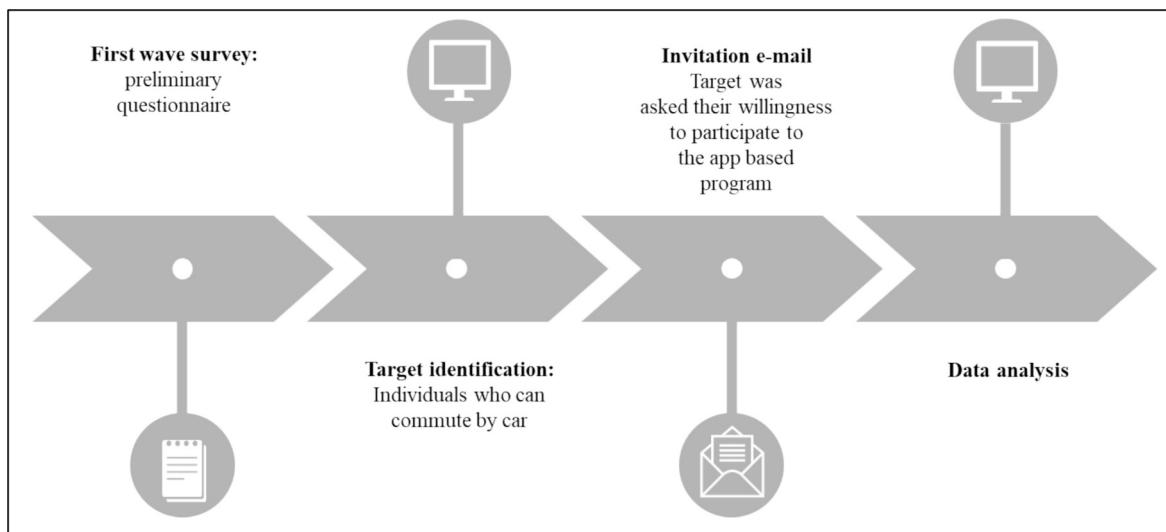


Fig. 1. Steps of the data collection and analysis process.

Table 1
Sample characteristics.

Variables	Sample		City of Cagliari (active population)
	N.	[%]	
Total sample	3044	100.0 %	
Gender			
Male	1493	49.0 %	48.3 %
Female	1551	51.0 %	51.7 %
Age			
Age 18–30	953	31.3 %	13.1 %
Age 31–40	485	15.9 %	15.9 %
Age 41–60	1415	46.5 %	48.2 %
Age > 60	191	6.3 %	22.8 %
Bachelor's degree or higher	1618	53.1 %	47.8 %
Employment status			
Student	854	28.1 %	n/a
Worker	2190	71.9 %	n/a
Presence of children in the household	1039	34.1 %	
# of members in the household (AVG)		2.97	2.14
# of cars per household (AVG)		1.84	1.50
Bike ownership	1632	53.6 %	n/a
Personal income per month			
Income 0–1000 €	946	31.1 %	36.7 %
Income 1001–2000 €	1515	49.8 %	47.5 %
Income 2001–3000 €	346	11.4 %	9.6 %
Income > 3000 €	237	7.8 %	6.2 %
Commuting distance [km] (AVG)		9.38	11.20
0 km - 1 km	48	1.6 %	n/a
1.1 km - 5 km	1085	35.6 %	n/a
5.1 km - 10 km	881	28.9 %	n/a
10.1–20 km	695	22.8 %	n/a
>20 km	335	11.0 %	n/a
Commute mode choice			
Personal car	1972	64.8 %	77.0 %
Transit	777	25.5 %	12.0 %
Active mobility	295	9.7 %	11.0 %
Intention to use the smartphone app			
No	1701	55.9 %	–
Yes	1343	44.1 %	–

n/a = not available; -- not applicable.

variables.

The two main endogenous variables of our study are:

- One binary variable representing the intention to participate in the Voluntary Travel Behavior Change (VTBC) program and use the VTBC application (yes vs. no).
- One multinomial variable representing the current commute mode choice: private motorized vehicle, transit, active mobility (bike and walking). For those who did not choose active mobility, it was considered a viable option only if their commuting distance was less than 5 km.

The latent constructs considered in our framework are those described in Section 3.2: *Social Norm*, *Emotions*, *Environmental Concern*, *Place Identity*, *Attitude toward Sustainable Mobility*, and *Perceived Behavioral Control toward Sustainable Mobility*.

The following hypotheses were formulated for the study:

- **H1.** Socio-demographic variables influence psycho-social variables, commute mode choice, and the intention to use the VTBC app.
- **H2.** Level-of-service variables and land-use variables influence commute mode choice.
- **H3.** *Social Norm*, *Emotions*, *Environmental Concern*, *Place Identity*, *Attitude toward Sustainable Mobility*, and *Perceived Behavioral Control toward Sustainable Mobility* exert a positive or non-significant influence on both the choice of a sustainable commuting mode and the intention to use the VTBC app.
- **H4.** The intention to use the VTBC app is influenced by the current commuting mode of transportation.

The modeling methodology employed in this study is the Integrated Choice and Latent Variable (ICLV) approach (Walker and Ben-Akiva, 2002). Latent constructs are specified as linear functions of some observed socio-demographic factors x_q and stochastic error terms ω_{wq} (structural equation):

$$LV_{wq} = \lambda_w x_q + \omega_{wq} \quad \omega_{wq} \sim \mathcal{N}(0, \sigma_{\omega_{wq}}) \quad (1)$$

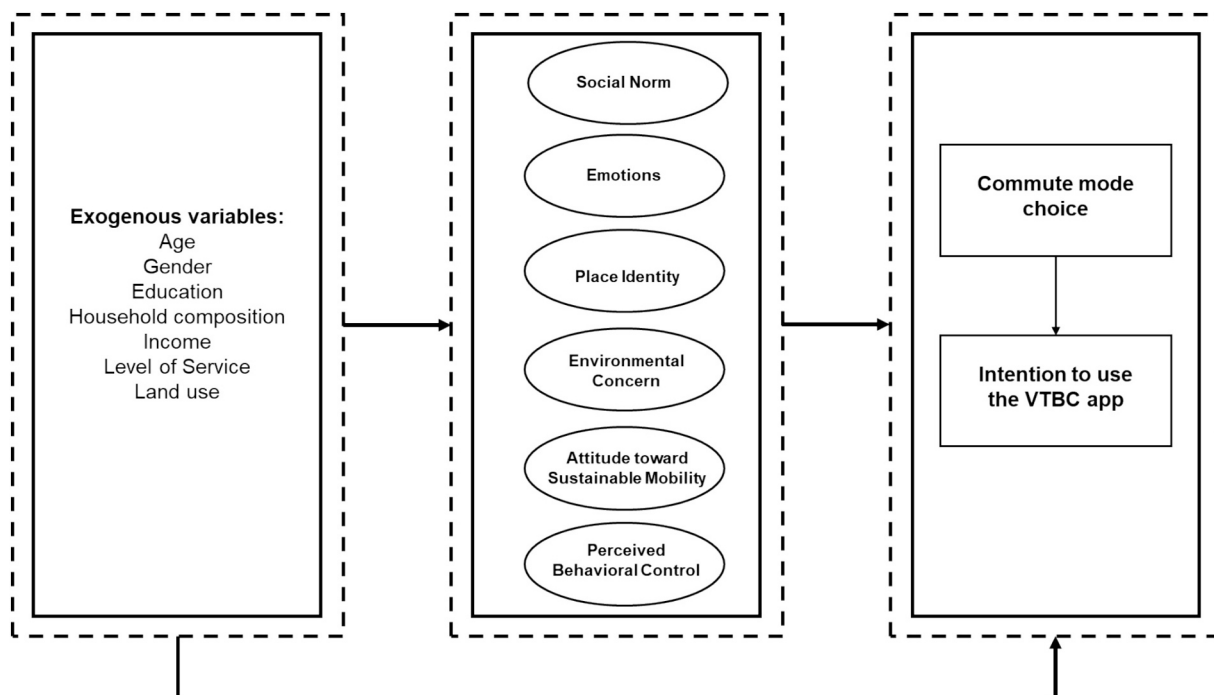


Fig. 2. Conceptual model.

For identification purposes, following the procedure proposed by Bolduc et al. (2005), we set the standard deviation of error term ω_{wq} equal to one.

The latent constructs cannot be observed directly by the analyst, and so the relationship between the observed variables and the latent constructs can be estimated only through the observed psycho-social indicators I_{rq} . The measurement equation for indicator r is given by:

$$I_{rq}^* = \delta_r + \zeta_r LV_{wq} + v_{rq} \quad v_{rq} \sim Logistic(0, \sigma_{v_{rq}}) \quad (2)$$

where δ_r is a constant of the r -th indicator, ζ_r is the influence exerted by latent variable LV_{wq} on the r -th indicator, and v_{rq} is a random error component. The parameter vector ρ_r defines the thresholds terms that link the observed value I_{rq} with response level s . To ensure that the thresholds increase in order, $\rho_{r,m}$ is defined as $\rho_{r,m} = \rho_{r,m-1} + \gamma_{r,m}$ where $\gamma_{r,m}$ are parameters to be estimated. Note that we set the first threshold to 0. Since the error components v_{rq} are assumed to be independently and identically distributed (i.i.d.) and to follow a logistic distribution, each measurement equation takes the form of an ordered logit model.

Let k denote the commuting mode option, where $k = 1, 2, 3$, and n represent the intention to use or not use the VTBC app, with $n = 1, 2$. Let u_{kq} represent the utility that person q assigns to travel alternative k . The utility function for the travel option k can be expressed as follows:

$$u_{kq} = \beta_{k,0} + \beta_{k,x} \mathbf{x}_q + \beta_{k,LV} \mathbf{LV}_q + v_{kq} \quad (4)$$

where $\beta_{k,0}$ is a constant, \mathbf{x}_q is a vector of observed explanatory variables (socio-demographics, level of service characteristics), \mathbf{LV}_q is a vector of latent variables, $\beta_{k,x}$ and $\beta_{k,LV}$ are vectors of coefficients. Lastly, v_{kq} is an i.i.d. distributed error term following a Gumbel distribution.

Additionally, the utility associated with the willingness to use or not use the VTBC app is given by:

$$y_{nq} = \alpha_{n,0} + \alpha_{n,x} \mathbf{x}_q + \alpha_{n,LV} \mathbf{LV}_q + \alpha_{n,MC} \mathbf{MC}_q + \xi_q \quad (5)$$

where $\alpha_{n,0}$ is a constant, \mathbf{x}_q is a vector of observed variables, \mathbf{LV}_q is a vector of latent variables. \mathbf{MC}_q is a vector of endogenous variables linked to the mode of transportation chosen, included as binary lagged variables (the same approach was employed in Bhat, 2015). $\alpha_{n,x}$, $\alpha_{n,LV}$, $\alpha_{n,MC}$ are coefficients to be estimated, and ξ_q is an independently and identically distributed Gumbel error term. It should be noted the presence of shared error terms in both u_{kq} and y_{nq} , which are the error terms of \mathbf{LV}_q represented in (1). Because of this, the impact of $\alpha_{n,MC}$ on y_{nq} cannot be regarded as distorted.

The conditional likelihood function for person q is defined as:

$$LL_q(\mathbf{a}_q, \mathbf{b}_q | \mathbf{x}_q, \mathbf{LV}_q) = \prod_{k=1}^3 \prod_{n=1}^2 \left\{ \frac{\exp(u_{kq})}{\sum_k \exp(u_{kq})} \times \frac{\exp(y_{nq})}{\sum_n \exp(y_{nq})} \right\}^{a_{kq} \times b_{nq}} \quad (6)$$

where \mathbf{a}_q and \mathbf{b}_q represent the vectors of choices made person q . The unconditional likelihood is then computed as:

$$LL_q(\mathbf{a}_q, \mathbf{b}_q, \mathbf{I}_q | \mathbf{x}_q) = \int_{LV_q} LL_q(\mathbf{a}_q, \mathbf{b}_q | \mathbf{x}_q, \mathbf{LV}_q) f_{LV}(\mathbf{LV}_q | \mathbf{x}_q) \prod_r f_r(I_{rq} | \mathbf{LV}_q) d\mathbf{LV} \quad (7)$$

Here, $f_{LV}(\mathbf{LV}_q | \mathbf{x}_q)$ represents the structural equations, and $f_r(I_{rq} | \mathbf{LV}_q)$ refers to the measurement equations.

To approximate the integral in eq. (7), simulation techniques are used. The simulated log-likelihood function is maximized to estimate all parameters in the model, using the PythonBiogeme software for this purpose (Bierlaire, 2016).

5. Results

5.1. Data analysis

What emerged from the analysis of the relationship between the intention to participate in the Voluntary Travel Behavior Change (VTBC) program and use the VTBC application and the commuting mode (Fig. 3) is that the intention is higher among transit users (47.6 %) and active mobility users (46.4 %) compared to the group of individuals who use to commute by car (42.4 %).

In Table 2 we present an analysis of the psycho-social characteristics of the sample, highlighting the differences between those who are willing to use the VTBC app and those who are not. To assess the differences between the means of psycho-social variables across the two groups, we employed a z-test. Regarding *Social Norm*, we observe a low level in both groups, with the “No” group showing a lower level compared to the “Yes” group. Examining the items related to the latent construct of *Emotions*, we identify some differences between the two groups: the “Yes” group experiences a higher sense of guilt when using a car and a greater sense of pride when using sustainable mobility options. Concerning the item *Environmental Concern*, the sample demonstrates a general sense of awareness and environmental responsibility. From the analysis of group differences, it is evident that individuals who intend to use the app have significantly higher awareness of the negative consequences of car use and a stronger sense of responsibility for environmental issues related to transportation choices. A similar trend is observed for the latent constructs *Place Identity* and *Attitude toward Sustainable Mobility*. The final construct, *Perceived Behavioral Control*, suggests that the sample generally believes using sustainable modes of transportation can be challenging. Even in this case, individuals who find it easier to use sustainable transportation show a higher intention to use the VTBC app.

5.2. Model results

This section presents a discussion of the model estimation results. We arrived at the final model after extensive testing of specifications. Note that, compared with the conceptual model presented in Fig. 2, we did not include in our final specification the latent variables *Social Norm*, *Emotions*, *Perceived Behavioral Control* and *Place Identity* as we did not find to exert a significant effect on the endogenous variables of our interest.

Table 3 presents the results of the structural equation component of the model, while results of the measurement equation model are reported in Appendix A. The latent construct *Environmental Concern* is influenced by gender, where females are more likely to be aware of environmental consequences and impacts compared to males. This result is consistent with previous research (Bouscasse et al., 2018; McCright and Sundström, 2013; Strapko et al., 2016; Vázquez-Paja et al., 2024; Xiao and McCright, 2015) and may be explained by the fact that women often take on caregiving roles within households, making them more sensitive to threats, such as environmental degradation, that could affect future generations (Xiao and McCright, 2015). Regarding age, environmental concern tends to decrease as age increases. Specifically, individuals aged 18–30 are the most likely to express concern about the environmental impact of car use, followed by those aged 31–40. This finding supports prior research on generational differences in *Environmental Concern* (Bouscasse et al., 2018; Casalegno et al., 2022; Poortinga et al., 2023; Wang and Wu, 2024) and may be related to the high level of youth-led protests and environmental movements active at the time of data collection, which aimed to raise public awareness about climate change. Lastly, consistent with previous literature (Mouratidis and Næss, 2024), our results show that higher levels of car ownership are associated with lower awareness of the environmental impacts of car use.

We now turn our attention to the construct of *Attitude toward*

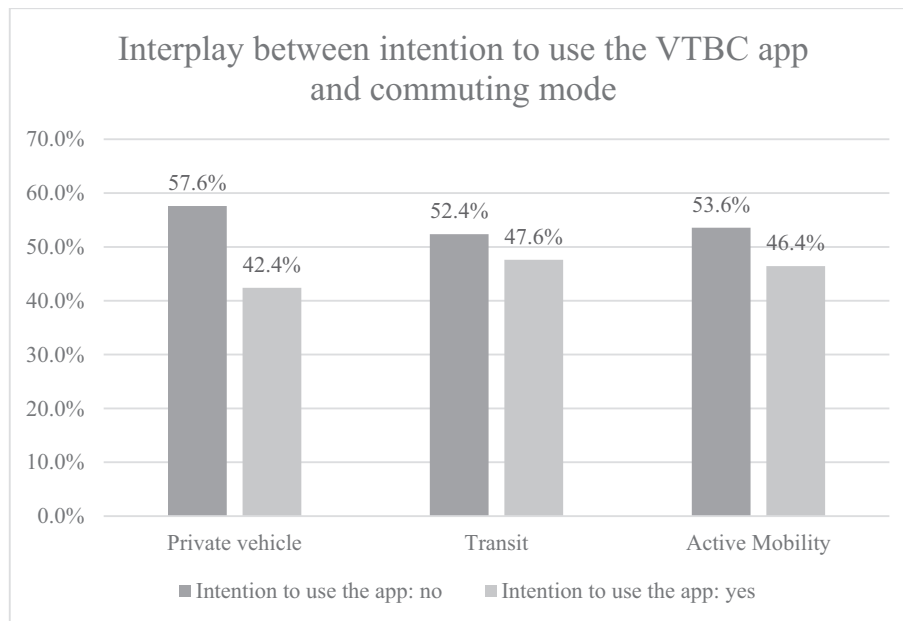


Fig. 3. Interplay between intention to use the VTBC app and commuting mode.

Table 2

Differences in psycho-social characteristics between individuals who are willing to use the VTBC app and those who are not.

	Items	AVG Total	Intention to use the VTBC app: Yes	Intention to use the VTBC app: No	Difference	Z stat
Social Norm	A1. Most of the people I know think I should use sustainable means of transport instead of the car.	2.558	2.521	2.587	-0.065	-1.485
	A2. Most of the people I know use sustainable means of transport instead of the car.	2.158	2.088	2.213	-0.125	-3.030
	B1. If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	2.475	2.488	2.266	0.223	4.986
Emotions	B2. If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	3.525	3.606	3.294	0.312	7.019
	B3. If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	2.845	2.771	2.903	-0.132	-2.990
	C1. I am aware that the use of private car has negative impacts on the environment and people's health.	4.404	4.465	4.356	0.109	3.881
Environmental Concern	C2. I am aware that I can personally contribute (by using the car less) to reducing pollution.	4.320	4.400	4.256	0.144	4.565
	C3. I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	3.453	3.557	3.372	0.185	4.338
	D1. This city is part of my identity and therefore I respect it.	4.453	4.507	4.410	0.097	3.568
Place Identity	D2. I feel at home in this city.	4.290	4.348	4.245	0.103	3.047
	D3. I feel I belong to this city and therefore I must contribute to make it a better place.	4.286	4.361	4.228	0.134	4.215
Attitude toward Sustainable Mobility	E1. I find that using sustainable means of transport instead of the private car is useful.	4.084	4.186	4.004	0.183	4.643
	E2. I find that using sustainable means of transport instead of the private car is pleasant.	3.585	3.701	3.493	0.209	4.576
	E3. I find that using sustainable means of transport instead of the private car is right.	4.233	4.333	4.155	0.178	5.463
Perceived Behavioral Control	F1. It would be easy for me to use sustainable means of transport.	2.848	2.927	2.786	0.141	2.619
	F2. I am sure that in the next week I can use sustainable means of transport.	2.985	3.109	2.887	0.222	3.909
	F3. For me using sustainable means of transport is impossible.	2.534	2.427	2.618	-0.192	-3.562

Sustainable Mobility. Interestingly, females display a higher level of positive attitude compared to males. This finding aligns with previous literature (Kawgan-Kagan, 2020) and can be explained by the fact that women are generally less inclined to attach symbolic value to private car ownership, unlike men (Sottile et al., 2019). Owning a personal bicycle also has a positive influence on this latent construct. It is likely that individuals who own a bicycle are more inclined to use it, which in turn fosters a more favorable *Attitude toward Sustainable Mobility*. Conversely,

as expected, a higher number of cars in the household negatively affects the construct. This is understandable, as households with more cars are more likely to rely on them, which can make it harder for individuals to consider or adopt sustainable transport alternatives. Furthermore, the results show that students exhibit a lower level of *Attitude toward Sustainable Transportation*. A possible interpretation is that students are among the most frequent users of public transportation. Given the often inadequate current Level of Service of public transport in the

Table 3
Determinants of latent constructs.

Explanatory variables	LV1 – Environmental Concern		LV2 – Attitude toward Sustainable Mobility	
	Coeff.	Robust T stat	Coeff.	Robust T stat
Gender (male = 1, female = 0)	-0.213	-5.05	-0.107	-2.53
Age 18–30	0.350	7.02	–	–
Age 31–40	0.165	2.77	–	–
Student (yes = 1, no = 0)	–	–	-0.299	-6.09
# of cars in the household	-0.122	-4.33	-0.165	-5.90

Note:- not significant

metropolitan area of Cagliari, they may find it less comfortable or useful compared to private car use.

Table 4 reports the outcomes of the model component simulating the choice of commuting modes of transport and the intention to use the VTBC app.

We begin with the analysis of the commuting mode choice component. Regarding the Level of Service variables, the logarithm of distance is negatively associated with the utility of active mobility. This is expected, as active mobility, unlike motorized modes, requires physical effort, making it less appealing as distance increases. Interestingly, the density of commercial buildings positively influences the utility of active mobility. This may be because workplaces located in areas with higher commercial density tend to be closer to residential areas, making active commuting more feasible. The number of transit stops within 100 m of the origin and destination also positively influences the utility of choosing transit over other alternatives, which is not surprising given the improved accessibility.

Turning to socio-demographic variables, we observed that gender, education level, professional status, and vehicle ownership all influence commute mode choice. In line with past research (Kawgan-Kagan, 2020; Sun et al., 2017), female individuals are more likely to use public transport, while males are more inclined to use active mobility. As expected, being a student is associated with a higher utility for commuting by public transport. Additionally, individuals without a university degree are more likely to use public transit. This may reflect income-related constraints, as public transportation is typically more affordable for individuals with limited financial resources. Unsurprisingly, a higher number of cars in the household is negatively associated with the utility of commuting by transit and active modes. In contrast, owning a personal bicycle is positively associated with the likelihood of using

Table 4
Parameter estimates of the binary endogenous variables.

Explanatory variables	Means of transport choice (base: private vehicle)				Intention to use the VTBC app (base: no)	
	Transit		Active Mobility		Yes	
	Coeff.	Robust T stat	Coeff.	Robust T stat	Coeff.	Robust T stat
Constant	-1.982	-8.11	0.728	2.37	-0.510	-5.66
Gender (male = 1, female = 0)	-0.229	-2.34	0.427	2.61	–	–
Student	1.855	14.68	–	–	–	–
Graduate	-0.415	-4.01	–	–	0.168	2.20
Income € 0–2000	–	–	–	–	0.215	2.81
Presence of children in the household	-0.567	-4.49	–	–	–	–
# of cars in the household	-0.432	-6.28	-0.392	-3.09	–	–
Personal bicycle available (yes = 1, no = 0)	–	–	0.866	5.11	0.213	2.85
Log of Commuting distance	–	–	-1.966	-14.13	–	–
Density of commercial buildings • 10 ⁻²	–	–	0.48	4.48	–	–
# of transit stops at origin	1.778	4.06	–	–	–	–
# of transit stop at destination	4.243	7.44	–	–	–	–
Transit	n/a	n/a	–	–	0.211	2.37
Latent variables						
LV1 – Environmental Concern	0.191	2.83	0.248	2.11	0.111	2.25
LV2 – Attitude toward Sustainable Mobility	0.471	6.70	0.778	6.04	0.174	3.54

n/a not applicable; – not significant

active mobility.

Finally, we analyze the impact of latent constructs on commuting choices. As expected, *Attitude toward Sustainable Mobility* positively influences the utility of both transit and active mobility alternatives, confirming previous findings (Ding et al., 2017; Sottile et al., 2019). Notably, we also find that *Environmental Concern* positively affects the likelihood of choosing sustainable transport options, as in Bouscasse et al. (2018) and Vázquez-Paja et al. (2024).

Lastly, we analyze the variables influencing the intention to use the VTBC application. First, we found that graduates are more likely to participate in such a program. A possible explanation is that individuals with higher education may be more receptive to information and better able to understand the potential benefits of such initiatives, both in terms of contributing to social change and winning a prize. People with lower incomes have a higher likelihood of expressing willingness to use the application compared to wealthier individuals, probably because they are attracted by the opportunity to win a prize. Bicycle ownership also plays a role, as individuals who own a bicycle may already be accustomed to using tracking applications, which makes the transition to the VTBC app more seamless. Regarding the effect of endogenous variables, we observe an early adopter effect: individuals who already use public transit are more likely to express an intention to use the VTBC app, corroborating what found by De Menezes Amorim and de Abreu e Silva (2025), though for a different type of app. We also cannot disregard the role of psycho-social variables in this decision. Indeed, individuals with a more positive *Attitude toward Sustainable Mobility* are more willing to use the VTBC app. *Environmental Concern* also influences this choice, individuals who are more aware of the negative consequences of car use and who feel personally responsible are more likely to participate. This finding is consistent with previous literature (Dastjerdi et al., 2019; Skarin et al., 2019), which has identified *Environmental Concern* as a key factor influencing the intention to take part in such programs. On the other hand, we found that emotions, social norms, place attachment, and perceived behavioral control did not have a statistically significant effect on this choice. However, when *Emotions* and *Place Identity* were included individually in the model, they did show significant effects. This can be attributed to the presence of multicollinearity between these variables and the variables of *Attitude toward Sustainable Mobility* and *Environmental Concern*.

5.2.1. Data fit

Model performance was assessed by comparing the ICLV model with an independent model. The independent model excludes the latent variables from the utility functions of the two endogenous variables,

while the socio-demographic variables influencing the latent constructs are included directly in the utility functions. As shown in Table 5, the final log-likelihood of the ICLV model (-24,202.118) is higher than that of the independent model (-24,300.180). Similarly, the adjusted likelihood ratio index $\bar{\rho}^2$ is also higher for the ICLV model (0.110 vs. 0.106). Since the two models are not nested, a non-nested adjusted likelihood ratio test was conducted to assess the significance of the difference in $\bar{\rho}^2$. The results indicate that the probability of the independent model outperforming the ICLV model is effectively zero.

Furthermore, the analysis of the predicted aggregate shares from the joint model shows that the predicted aggregate probability of each alternative closely matches the actual distribution observed in the sample.

5.2.2. Role of latent variables in model

The ICLV model makes it possible to decompose the direct and indirect effects of socio-demographic variables on utility. Specifically, these variables influence the intention to use the VTBC app and mode choice both indirectly, through latent variables, and directly. Indeed, each latent variable includes a deterministic component, represented by the socio-economic characteristics of individuals included in the structural equation, that influence both the utilities of mode choice and the intention to use the VTBC app. At the same time, the same socio-demographic characteristics directly affect utility. By comparing the indirect effects of socio-demographic variables, mediated by latent variables, with their direct effects on utility, it is possible to identify the sources of deterministic heterogeneity in utility functions (Hess et al., 2018).

The results of the computation of direct and indirect effects are reported in Table 6. Not all variables influencing commuting mode choice have the same impact on the intention to use the VTBC app. For instance, graduates are more likely to participate in the VTBC program, yet they are less inclined to use public transport. Income level, while relevant for the intention to use the app, does not appear to influence commuting mode choice. Unexpectedly, the number of cars in a household does not have a direct effect on the intention to use the VTBC app, although it does affect commuting mode choice. However, the number of cars exerts an indirect effect through the two latent variables *Attitude toward Sustainable Mobility* and *Environmental Concern*. Similarly, gender influences the intention to use the VTBC app indirectly through latent variables, while for commuting mode choice its effect is both direct and indirect. Overall, women are more likely to show interest in the app, which is consistent with the fact that they are also more likely to use public transport. As for age, its influence is entirely indirect for both commuting mode choice and the intention to use the VTBC app.

These findings can be interpreted by recognizing that the decision to use a VTBC app follows a different cognitive process from the selection of a commuting mode, which is often constrained by individual

circumstances and needs. A similar conclusion was reached by Skarin et al. (2019), who found that the factors influencing participation in a VTBC program differ from those affecting the decision to change travel behavior. Despite these differences, some variables are shared and exert consistent influence across both dimensions of choice. In particular, latent variables play a role in shaping both app adoption and commuting behavior, reinforcing the idea that individuals predisposed to environmentally friendly attitudes are not only more likely to adopt sustainable mobility practices but also more eager to contribute to broader behavioral change.

5.2.3. Pseudo-elasticity effects

The results presented in Table 4 and Table 6 do not quantify the magnitude of the direct and indirect effects of the independent variables on the dependent variables. Understanding these effects is crucial for identifying which variables exert the greatest influence on the decision-making process for choosing a commute mode and using the VTBC app. To achieve this, we compute pseudo-elasticity effects, which is a metric that measures how the probability of a choice changes, in an absolute value, when a specific variable of interest is modified from point A to point B. More details can be found in Piras et al. (2021).

The results of the computation of pseudo-elasticity effects are reported in Table 7. What is particularly striking is that the largest effect on the intention to use the app is exerted by the endogenous variable. Specifically, if all individuals in the sample were transit commuters, the probability of choosing to use the app would increase by 3.82 %. That said, it is interesting to observe that the magnitude of each variable, whether acting directly or indirectly through latent variables, on the intention to use the app does not vary significantly, with pseudo-elasticity values ranging approximately from plus or minus 0.2 % to plus or minus 3.5 %. This finding suggests that, in addition to socio-demographic characteristics and psychological factors associated with sustainable mobility and environmental motivations, other variables, e. g., technophilia, also influence the intention to use such apps.

6. Policy implications

The results of the study presented here provide different points of reflection in terms of the evaluation of the effectiveness of Voluntary Travel Behavior Change (VTBC) actions if implemented through smartphone applications.

First, at an aggregate level, we observed that not everyone is willing to participate in an app-based VTBC program. However, the effectiveness of such strategies depends heavily on the participation rate among those invited, making it essential to encourage as many people as possible to take part in the program. Numerous studies and research emphasize the importance of engagement and generalized marketing efforts to encourage even the most reluctant individuals to participate.

Table 5
Model Measures of Goodness-of-Fit.

Goodness of fit measures					
Disaggregate measures of fit					
	ICLV model		Independent model		
Final log-likelihood	-24,202.118		-24,300.180		
Constants only final log-likelihood			-27,245.153		
Number of parameters (not including constants)	53		47		
Adjusted likelihood ratio index $\bar{\rho}^2$	0.110		0.106		
Non-nested adjusted likelihood ratio test			$\Phi (-95.062) < << 0.001$		
Aggregate measures of fit					
	Means of transport: car	Means of transport: transit	Means of transport: active mobility	Intention to use the app: no	Intention to use the app: yes
Real sample share	64.78 %	25.53 %	9.69 %	55.88 %	44.12 %
Aggregate predicted share	65.27 %	25.68 %	9.05 %	55.95 %	44.05 %

Table 6
Direct and indirect effect of socio-economic variables in model utilities.

	Direct	LV1 – Environmental Concern	LV2 – Attitude toward Sustainable Mobility	Combined LV effect	Overall effect
Commute mode choice (transit)					
Male (vs. female)	-0.23	-0.04	-0.05	-0.09	-0.32
Student (vs. worker)	1.86		-0.14	-0.14	1.71
Aged 18–30 (vs. aged >40)		0.07		0.07	0.07
Aged 31–40 (vs. aged >40)		0.03		0.03	0.03
Graduate (vs. no graduate)	-0.42				-0.42
Yes children (vs. no children)	-0.57				-0.57
1 car (vs. no cars)	-0.43	-0.02	-0.08	-0.10	-0.53
Commute mode choice (active mobility)					
Male (vs. female)	0.43	-0.05	-0.08	-0.14	0.29
Student (vs. worker)			-0.23	-0.23	-0.23
Aged 18–30 (vs. aged >40)		0.09		0.09	0.09
Aged 31–40 (vs. aged >40)		0.04		0.04	0.04
1 car (vs. no cars)	-0.39	-0.03	-0.13	-0.16	-0.55
Bicycle (vs. no bicycle)	0.87				0.87
Intention to use the VTBC app (yes)					
Male (vs. female)		-0.02	-0.02	-0.04	-0.04
Student (vs. worker)			-0.05	-0.05	-0.05
Aged 18–30 (vs. aged >40)		0.04		0.04	0.04
Aged 31–40 (vs. aged >40)		0.02		0.02	0.02
Graduate (vs. no graduate)	0.17				0.17
1 car (vs. no cars)		-0.01	-0.03	-0.04	-0.04
Bicycle (vs. no bicycle)	0.21				0.21
Income less 2000 (vs. income more than 2000)	0.22				0.22
Transit as a commuting mode (vs. no transit)	0.21				0.21

In our study, the pre-engagement phase was extensive, including announcements in local newspapers and TV programs, and billboard advertisements. Despite these efforts, only a reduced number of individuals agreed to participate, suggesting a need to rethink this phase. Improvements to the pre-engagement process could include placing greater emphasis on monetary prizes for those who change their travel behavior or offering rewards for participation itself, rather than exclusively linking them to actual behavioral changes. Another approach to further increase participation could be the deployment of a more tailored marketing campaign. Such a campaign could consider the psychological factors that influence program participation. For example, the communication strategy could focus on raising awareness about the negative consequences of car usage, which model results in our paper highlighted to have a role. As individuals become more informed and develop stronger sustainability-related values, they may become more willing to participate in these programs. Another important aspect of the communication campaign is targeting demographic groups that are less inclined to participate. In our case, model results indicate that individuals with higher incomes and those with lower education levels are less likely to engage with app-based VTBC programs. Tailored messages targeting these specific groups could have enhanced the effectiveness of the campaign.

The second key finding from our study is that individuals who already use sustainable modes of transportation were the most likely to use the VTBC app. This result is not entirely unexpected, given the opportunity to win prizes for using sustainable transportation. However, it raises an important issue for consideration. In Italy, within the framework of Home-Work Travel Plans and Sustainable Urban Mobility Plans, mobility management actions are often implemented through apps for smartphones. These apps allow everyone to participate and potentially win prizes, regardless of whether they already use sustainable modes of transport or rely on private motorized vehicles. Often, the success of such programs is measured in numerical terms, such as the total kilometers traveled by bicycle or public transport, without examining whether these figures represent an actual increase in the use of sustainable transport modes or merely reflect behavior from individuals

who were already using them. If the goal is to genuinely evaluate the effectiveness of such measures, greater attention must be paid to this distinction.

Another challenge that emerged from the data analysis, similar to the one previously mentioned, relates to the self-selection of participants, not only in terms of their choice of transportation modes but also from a psychological profile perspective. Both results of descriptive statistics and econometric model estimation indicate that individuals who are more aware of the problems caused by car use and who exhibit a stronger attitude toward sustainable mobility are more likely to engage with such programs. From a phenomenological standpoint, this is understandable, as those who are already predisposed to behavioral change or inclined toward sustainable mobility are the easiest to involve in these types of programs. However, this also means that the results of behavioral change observed in these programs and experiments cannot be easily generalized to the broader population. Hence, policymakers should not assume that the behavioral changes observed in a pilot program will be replicated across the entire population. Instead, they should anticipate a significantly lower level of success. In light of this, it is important to assess whether such measures merit financial investment and to weigh their benefits and drawbacks against infrastructural or legislative measures.

Another consideration concerns the accelerated uptake of transport apps, including the recent development of transport super apps (Hasselwander, 2025), which integrate multiple services within a single application and brand, covering diverse aspects of daily life such as e-ticketing and e-shopping. The characteristics of these apps are primarily designed to deliver direct benefits to individual users, as they facilitate everyday tasks, from buying tickets to ordering food and goods. On the other hand, VTBC apps aim to encourage users to change their travel behavior for the broader benefit of society and the environment. It is therefore unclear whether transport apps genuinely foster behavioral change in travel or simply attract users already inclined to adopt such features. Hence, the motivations for using these two types of apps could differ, and the strategies to promote them should also differ. A one-size-fits-all advertising campaign is inadequate: for VTBC apps, emphasis

Table 7
Pseudo-elasticity effects.

	App: Yes	App: No	Mode: Private vehicle	Mode: Transit	Mode: Active mobility
Attitude toward Sustainable Mobility					
	-0.23				
Gender: All male	%	0.23 %	0.50 %	-0.34 %	-0.30 %
		-0.22			
Gender: All female	0.22 %	%	-0.48 %	0.27 %	0.41 %
Employment:	-0.91				
Student	%	0.91 %	1.81 %	-0.93 %	-1.69 %
Employment:		-0.35			
Worker	0.35 %	%	-0.87 %	0.75 %	0.24 %
No cars in the household	1.28 %	-1.28 %	-2.73 %	1.78 %	1.82 %
Environmental Concern					
	-0.29				
Gender: All male	%	0.29 %	0.38 %	-0.29 %	-0.18 %
		-0.28			
Gender: All female	0.28 %	%	-0.36 %	0.23 %	0.24 %
		-0.58			
Age: 18–30	0.58 %	%	-0.70 %	0.42 %	0.54 %
		-0.08			
Age: 31–40	0.08 %	%	-0.05 %	-0.04 %	0.17 %
	-0.36				
Age: over 40	%	0.36 %	0.52 %	-0.44 %	-0.16 %
No cars in the household	0.60 %	-0.60 %	-0.75 %	0.55 %	0.39 %
Discrete					
Gender: All male			0.83 %	-2.14 %	2.52 %
Gender: All female			-0.58 %	1.95 %	-2.61 %
Employment:					
Student			-20.58 %	23.68 %	-5.93 %
Employment:					
Worker			9.06 %	-9.84 %	1.50 %
Education: Less than a bachelor's degree	-2.16 %				
	%	2.16 %	-2.64 %	3.04 %	-0.77 %
Education:					
Bachelor's degree or more	1.90 %	-1.90 %	2.95 %	-3.24 %	0.56 %
No children in the household			-1.97 %	2.22 %	-0.50 %
At least one child in the household			5.42 %	-6.05 %	1.21 %
No cars in the household			-13.79 %	11.48 %	4.43 %
Bicycle: No	-2.77 %				
	%	2.77 %	1.76 %	0.67 %	-4.66 %
		-2.40			
Bicycle: Yes	2.40 %	%	-1.45 %	-0.74 %	4.19 %
Income: Less € 2000	2.62 %	-2.62 %			
	%	%			
Income: More € 2000	-2.59 %	2.59 %			
	%	%			
Use transit as commuting mode: Yes	3.82 %	-3.82 %			
	%	%			
Use transit as commuting mode: No	-1.30 %	1.30 %			
	%	%			
Commuting distance (-10 %)			-0.82 %	-0.35 %	2.23 %
Density of commercial buildings (-10 %)			0.21 %	0.10 %	-0.60 %
# of transit stop at destinations (-10 %)			1.28 %	-1.45 %	0.33 %
# of transit stop at origins (-10 %)			0.40 %	-0.48 %	0.14 %

should be placed on environmental and societal benefits, while for transportation super apps the focus should be on individual advantages and practical tools.

The final remark concerns the period of data collection of our study, between 2019 and 2020, prior to the restrictions imposed by governments to curb the spread of COVID-19. Nevertheless, car use levels five years after the pandemic have not changed significantly. In Italy, for example, the modal share of private car use for commuting increased from 69.7 % in 2019 to 70.3 % in 2024 (ISTAT, 2024). This confirms that the need for strategies to reduce car dependency remains pressing, and that policymakers should not abandon the use of VTBC apps, while also considering the reflections discussed above.

7. Conclusions

Understanding who is more likely to participate in an app-based Voluntary Travel Behavior Change (VTBC) program is a question of critical importance for the effectiveness of informational measures aimed at promoting sustainable mobility. However, this remains an area where knowledge is still limited. Existing literature has only occasionally examined this issue in depth, and policy-makers and practitioners who implement such measures often appear to overlook its significance. Frequently, the success of these programs is overstated, despite the limited number of participants they manage to engage. Moreover, those who do participate are often already users of sustainable transport modes or individuals with a strong predisposition toward travel behavior change. This study seeks to contribute to filling this gap by analyzing the factors that influence the intention to participate in an app-based VTBC program and its relationship with commuting mode choice. To this end, we estimated a joint Integrated Choice and Latent Variable (ICLV) model. The analysis is based on data collected from a sample of 3044 individuals as part of a VTBC program conducted in the metropolitan area of Cagliari, a mid-sized city in Italy.

At an aggregate level, we observed that 44.1 % of respondents indicated an intention to use the VTBC application. This percentage varies depending on the mode of transportation chosen for commuting. In particular, individuals who use private cars are less inclined to participate in such programs. The results of the model estimation provide several insights into the factors influencing the intention to adopt a VTBC application. With respect to socio-economic characteristics, the analysis reveals that individuals with lower income levels and those with higher levels of education are more likely to engage with the program. Additionally, certain psycho-attitudinal variables play a significant role in shaping this intention. Specifically, a positive *Attitude toward Sustainable Mobility* and heightened *Environmental Concern* emerge as important predictors. The influence of the endogenous variable representing the choice to use public transportation for commuting also proves to be significant in explaining the intention to adopt the application. Taken together, these findings support the initial hypothesis concerning the existence of a self-selection mechanism. Individuals with a psychological predisposition toward sustainability and those who already use environmentally friendly modes of transport are more inclined to participate in app-based mobility management initiatives.

Furthermore, the computation of direct and indirect effects, mediated through latent variables, together with the analysis of pseudo-elasticity effects, sheds light on the differentiated impacts of the explanatory variables on the intention to use the VTBC application. First, among the variables influencing the intention to use the app, the endogenous variable related to public transit use has the largest magnitude. The joint model estimation ensures that this effect is not overestimated. Second, while certain socio-demographic variables, particularly those influencing the latent constructs, show an effect direction consistent with commute mode choice, others display direct effects that differ in both direction and magnitude. This suggests that the decision-making process involved in selecting a mode of transportation is different from that involved in deciding whether to adopt the

application.

From a policy standpoint, these findings underscore the importance of promoting the application effectively in order to maximize participation and, consequently, induce meaningful changes in travel behavior. Moreover, since the factors influencing mode choice partly differ from those affecting the intention to use the VTBC app, strategies to encourage app use should differ from those aimed at changing travel behavior. Finally, it is crucial to interpret the outcomes of such programs with caution, as the observed levels of success may be influenced by the fact that certain individuals are inherently more predisposed to participate.

Our study is not without limitations. First, it examined the intention to use the VTBC app, rather than actual usage. The actual usage rate may differ from the intention to use it, especially depending on the perceived burden of using the app and the required number of usage days. Second, we classified as not interested in using the VTBC app and joining the program all individuals who did not respond to our invitation. It is possible that some of them did not express their intention to use the app because they did not see the invitation email or experienced other technological issues. Therefore, it is important to note that this may influence the results of the model on the propensity to use the app. Nevertheless, one of the main issues of these programs is the attrition effect (Verzosa et al., 2021), so it is reasonable to assume that most of the individuals who did not respond to the invitation were not interested in using the app. Third, we did not assess participants' level of tech-savviness or their willingness to share private location data. This omission was due to our primary focus on understanding the process of participating in a VTBC program, and specifically, on exploring potential psychological biases related to sustainable mobility and environmental concern. Future research should address this aspect, as the success of such programs depends heavily on participation rates, and technological factors may influence engagement when the programs are implemented via apps. Lastly, the program offered incentives only to those who chose sustainable mobility options during the test. This may

have led to a higher proportion of participants who were already inclined to use such modes of transportation. Future studies should explore both participation rates and actual app usage in scenarios where equal incentives are offered to all participants, regardless of their mobility choices.

CRedit authorship contribution statement

Francesco Piras: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giovanni Tuveri:** Writing – review & editing, Investigation, Data curation. **Eleonora Sottile:** Writing – review & editing, Project administration, Investigation. **Tariq Naveed:** Writing – review & editing, Writing – original draft. **Italo Meloni:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition.

Declaration of competing interest

None.

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Appendix A

Table 8
Results of the estimation of measurement equation models.

ITEMS	Gamma 2		Gamma 3		Gamma 4		Constant		Latent variable loading	
	Coeff.	Robust T stat	Coeff.	Robust T stat	Coeff.	Robust T stat	Coeff.	Robust T stat	Coeff.	Robust T stat
LV1. Environmental Concern										
C1.	1.494	8.07	1.530	11.3	4.131	17.68	8.000	16.75	2.791	13.79
C2.	1.567	8.06	2.016	9.56	4.814	11.04	9.306	11.11	3.843	9.13
C3.	1.189	19.62	1.244	25.03	2.666	35.75	3.272	25.28	1.425	23.03
LV2. Attitude toward Sustainable Mobility										
E1.	1.215	12.64	1.354	16.55	2.763	23.69	6.055	21.68	2.395	18.43
E2.	1.351	19.51	1.376	23.41	2.122	27.78	4.262	23.98	1.871	22.05
E3.	1.263	9.16	2.360	18.02	2.960	21.65	7.571	22.11	2.537	16.53

Data availability

The authors do not have permission to share data.

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