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Promoting a sustainable behavioral shift in commuting choices: the role of previous intention and "personalized travel plan" feedback

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ABSTRACT

According to the European Environment Agency (European Environmental Agency, EEA, 2018), road transport is responsible for 72% of all transport-related greenhouse gas emissions in the European Union (EU), which accounts for 25% of total energy-related emissions (Eurostat, 2018). Thus, it is crucial to identify drivers and barriers to more sustainable transport behaviors. In this regard, the Norm Activation Model and Theory of Planned Behavior have often been used as conceptual frameworks for predicting such behaviors. The present study aimed to analyze the differential impact of both socio-psychological factors and persuasive messages sent through a *Personalized Travel Plan (PTP)* on Sustainable Transport Choices (STC). To reach this aim we administered a survey two times (T1: Oct./Dec. 2020; T2: March/May 2021) to 398 car users. Measures of constructs included in the Norm Activation Model and the Theory of Planned Behavior, such as behavioral intention, attitude, perceived behavioral control, beliefs, and personal and social norms, were detected. Participants were then exposed to a PTP built on feedback information regarding kilocalories, CO_2 emissions, cost, and time savings when using sustainable transport compared to driving a car. Structural Equation Modeling (SEM) analysis shows that intention to use sustainable transport in T1 is on one side directly predicted by personal norm, perceived behavioral control, and attitude, and on the other side emerged as the main predictor of sustainable travel choices in T2, together with kcal spent, whereas time was the major barrier. Implications and future developments are discussed in the light of the conceptual framework.

1. Introduction

Sustainable mobility is now at the forefront of policies aimed at reducing climate change impacts and improving environmental quality, due to a growing understanding of the significant environmental impacts caused by greenhouse gas emissions from the transport sector. According to the European Environment Agency (European Environmental Agency, EEA, 2018), road transport is

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responsible for 72 % of all transport-related greenhouse gas emissions in the European Union, which accounts for 25 % of total energy-related emissions (Eurostat, 2018). This has serious consequences, including high mortality rates and increased air pollution-related illnesses like cancer and respiratory diseases (Eckelman & Sherman, 2018). Concrete measures are needed to promote sustainable mobility practices to contrast climate change and effectively reduce its adverse health effects. Structural and behavioral interventions are the two basic strategies to promote behavior change. Planning and regulatory initiatives such as petrol and road pricing, creating cycle and bus lanes, and pedestrianizing city centers are examples of structural interventions (Javaid et al., 2022). In contrast, behavioral interventions change people's attitudes, beliefs, and perceptions about sustainable mobility alternatives while promoting self-control (Javaid et al., 2022). According to transportation research, socio-psychological aspects are important in shaping people's travel decisions (Dütschke et al., 2022; Liu et al., 2017). In particular, social, cognitive, and emotional dimensions can be important in travel mode choices. Indeed, the present study is part of a research project focused on providing personalized commuting information through a Personalized Travel Plan (PTP) to promote sustainable travel choices like public transport, walking, or cycling (see Giubergia et al., 2023). The study aims to explore how socio-psychological factors and information about travel behavior, including comparative data between two alternative scenarios, influence travel choices. The comparison concerned the difference between car use (i.e., the actual travel choice) and travel alternatives (i.e., public transport, cycling, or walking). The focus of the study is also on behavioral intention and its antecedents, which are addressed in the theoretical integrated framework presented in the following pages. Our work adds to the current literature in several ways: expanding on Piras et al. (2021), we investigated whether different socio-psychological variables measured at Time 1 (Oct./Dec. 2020), which are comprised in the TPB and NAM, and subsequent personalized transport feedback for different transport choice modes delivered at Time 2 (Mar./May 2021), i.e., public transport, walking, and cycling, could differentially influence sustainable transport choices. Unlike most studies that used self-monitoring strategies, we conveyed personalized information about CO_2 emissions, Calories consumed, Time, and Costs spent commuting.[2]

1.1. Norm Activation model (NAM) and Theory of Planned behavior (TPB)

Alongside contextual factors, there are some theoretical models, such as the Norm Activation Model (NAM; Schwartz, 1977; Schwartz & Howard, 1984) and the Theory of Planned Behavior (TPB, Ajzen, 1985; Ajzen & Fishbein, 1980), that have been extensively considered to explain travelers' behaviors. The Norm Activation Model was initially proposed to explain prosocial behavior, considering constructs such as awareness of consequences, ascription of responsibility, and personal norm. Later, NAM has also been used for predicting pro-environmental intentions and behaviors (e.g., Bamberg & Schmidt, 2003; Onwezen et al., 2013; Vining & Ebreo, 1992), considered as examples of altruistic behaviors. This model postulates that altruistic and pro-environmental behaviors are related to personal norm, i.e., the feeling of moral obligation to perform a behavior or to refrain from it, which in turn activates two kinds of beliefs: the first is ascription of responsibility, defined as the responsibility people have towards the consequences of prosocial or pro-environmental actions, and the second is awareness of consequences, defined as the awareness people have of the effects of their prosocial or pro-environmental actions on others (de Groot & Steg, 2009; Rezaei et al., 2019). Thus, according to this view, the personal norm is linked to the system of beliefs that activates it and serves as a direct antecedent of action (Stern, 2000; Stern et al., 1999; Stern et al., 1995). In other words, NAM proposes that pro-environmental behavior derives from a feeling of moral obligation to act in favor of the environment, and such a feeling is triggered by the system of beliefs, namely awareness of consequences and ascription of responsibility. These constructs that characterize NAM are also included in the Value-Belief-Norm theory (VBN; Stern et al., 1999; Stern, 2000), which also contains values as the first level of the prediction set. These theoretical models and constructs have often been used in research on sustainable transport, e.g., focusing on active transport (cycling and walking) (Kim et al., 2023), changes in travel mode (Lind et al., 2015), and acceptance of car use reduction (Jakovcevic & Steg, 2013).

The Theory of Planned Behaviour (Ajzen, 1985) represents a commonly used theoretical framework in research investigating behavior and behavior change, including environment-related intentions and actions, and postulates that people make rational, planned, and interest-motivated decisions (Abrahamse & Steg, 2011). According to TPB, the intention to perform a behavior is the closest antecedent of the behavior itself; behavioral intention can be defined as the extent to which people are willing to try to perform the target behavior. This theory emphasizes that intention is determined by attitude related to the target behavior, i.e., the favorable or unfavorable evaluation of such behavior, perceived behavioral control, i.e. the perceived level of difficulty/ease in performing the behavior, and subjective norm, that has to do with individual's perception of the extent to which significant others would agree (or disagree) with the behavior, and also with the individual's motivation to conform to this social pressure (Abrahamse & Steg, 2011). TPB framework has been used to investigate various pro-environmental behaviors, such as recycling (e.g., Aboelmaged, 2021; Kumar, 2019; Mak et al., 2019), consumption of sustainable food (e.g., Siripipatthanakul et al., 2022; Qi & Ploeger, 2021; Vermeir & Verbeke, 2008), and intentions to purchase a sustainable house (e.g., Judge et al., 2019). Regarding the transportation research literature there were studies carried out on intention to use public transport like metro and bus (e.g., Ambak et al., 2016; Shaaban & Maher, 2020; Zailani et al., 2016), car purchase intentions (e.g., Shalender & Sharma, 2021), willingness to reduce car use (e.g., Schoenau & Müller, 2017), car sharing (e.g., Jain et al., 2021; Mattia et al., 2019; Zhang & Li, 2020), and bike sharing (e.g., Kaplan et al., 2015; Si et al.,

[2] It is important to notice that, alongside behavioral feedback, normative information was also provided. This choice was made to test the effect of descriptive and injunctive norms on STC but it was beyond the aims of our study (see Giubergia et al., 2023). To exclude a possible effect of norms manipulation on our model we have conducted a preliminary ANOVA with norms manipulation as a between-subject factor and Sustainable Transport Choice vs Car as a Dependent Variable. The analysis did not show significant differences between experimental conditions, so the role of norms was not further investigated.

2020).

In their systematic review of this topic, Hoffmann and colleagues (2017) showed that the main predictors of alternative travel choices are TPB constructs, i.e., intention, perceived behavioral control, and attitude. Also, Lanzini and Khan's meta-analysis (2017) supported the TPB framework for predicting greener transport choices. Some studies on pro-environmental behaviors have compared or integrated TPB with NAM (or VBN). For instance, Kaiser and colleagues (2005) compared TPB and VBN in their ability to explain saving behaviors, and the results revealed considerable explanatory power for both theories. Fornara and colleagues (2016) found the significant role of attitude toward the target behavior (derived from TPB), personal norm, and ascription of responsibilities (included in NAM and VBN) on the intention to use renewable energy sources in household contexts. Lai and colleagues (2020) showed the direct weight of personal norm and the indirect impact through the ascription of responsibility and social norms on the intention to purchase meat-based products.

1.2. Social norms

Social influence is the term used to describe psychological change brought on by other people's conduct (Cialdini & Goldstein, 2004). Social norms are a person's perceptions of normal and approved behavior within a group (Schultz, 2022) that guide behavior, especially under high uncertainty (Cialdini & Goldstein, 2004). The Focus Theory of Normative Conduct (Cialdini et al., 1991) distinguished two types of social norms: descriptive norm, which provides information about the adaptive and effective behaviors in each situation, that is, referring to what most people do, and injunctive norm, which represents what most people would approve or disapprove, that is similar to the subjective norm of the TPB (Ajzen, 1985). Framing messages based on social norms is one of the best strategies for promoting pro-environmental behaviors (Cialdini & Jacobson, 2021). Persuasive messages based on injunctive and descriptive norms have been shown to have a positive impact on reducing energy consumption (e.g., Bator et al., 2014; Brandon & Lewis, 1999; Bergquist & Nilsson, 2019; Carrico & Riemer, 2011; De Dominicis et al., 2019; Dwyer et al., 2015; Fornara et al., 2016; Schultz et al., 2018), recycling and littering (e.g., Bator et al., 2011; Borg et al., 2020; Carrus et al., 2009; Cialdini et al., 1990; de Groot et al., 2013; de Kort et al., 2008; Fornara et al., 2011), water conservation (e.g., Aronson & O'Leary, 1982; Bernedo et al., 2014; Dorigoni & Bonini, 2023; Liang et al., 2018; Lede et al., 2019; Mortensen et al., 2019) and adopting a sustainable diet (e.g., Amiot et al., 2018; Lai et al., 2020; Raghoebar et al., 2020; Sparkman & Walton, 2017; Sparkman et al., 2020) (for a review, see Abrahamse & Steg, 2013; Bergquist et al., 2019). Social norms-based influence has also been used to promote sustainable mobility behaviors alternative to car use, leading to discordant results. Indeed, a field experiment by Kormos and colleagues (2015) found that the perception of descriptive norms in favor of sustainable mobility led to greater use of alternatives to the private car. In contrast, from research by Gardner and Abraham (2010), the social norm message had an unintended, or "boomerang," influence on behavior, leading people who expected other people to use private cars less (descriptive norm) to choose to use them more. About the intention to use public transport, a positive effect of social norms was found through behavioral control, attitude towards sustainable transport, and personal norm (Bamberg et al., 2007). According to Klöckner and Blöbaum (2010), the choice to use alternative means of transportation was positively influenced by social norms through the activation of personal norm and the habit of using the private car. In a recent experimental study (Manca et al., 2023), messages based on injunctive and descriptive norms affected behavioral intention through attitudes regarding sustainable transportation, confirming previous studies in which injunctive and descriptive rules had an impact on green travel intention (Ru et al., 2018; Zhang et al., 2016). Finally, an experiment by Piras and colleagues (2021) found that messages based on injunctive norms significantly affect the future intention to use sustainable transportation modes and reduce private car use.

1.3. The role of motivations in the promotion of pro-environmental behaviors

The choice to adopt a given behavior depends also on individual motivation. Researchers have tried to identify the motivational drivers that lead people to act pro-environmentally and in support of environmental sustainability initiatives (e.g., de Groot & Steg, 2010; Moser & Kleinhückelkotten, 2018; Sharpe et al., 2021; Stikvoort & Juslin, 2022; van Riper et al., 2020). In literature, it is possible to identify two motivational sources capable of predicting behavior, i.e., intrinsic and extrinsic motivations. Intrinsically motivated behaviors "are those whose motivation is based in the inherent satisfactions of the behaviors *per se*, […] whereas extrinsic motivation is focused toward and dependent on contingent outcomes that are separable from the action *per se*" (Deci & Ryan, 2002, p. 10). Intrinsically motivated people to act pro-environmentally do so out of a sense of fulfillment and pleasure in the behavior itself (Steg, 2016). This pleasure is generated by a moral obligation to act pro-environmentally and under one's personal values (de Groot & Steg, 2010; Masson & Otto, 2021; Pelletier et al., 1998; Sharpe et al., 2021). Despite the internalization of biospheric values and moral obligation, in many situations, people may find themselves in a position not to act pro-environmentally (Ku & Zaroff, 2014; Steg et al., 2014). Implementing certain pro-environmental behaviors can be costly, effortful, and time-consuming, so people may seek a reward that motivates them to act. Among the extrinsic motivational levers for promoting pro-environmental behaviors, incentives (e.g., cost and tax reductions or rewards) and monetary disincentives (e.g., tax increases or fines) are among the most studied and used (e.g., Jakovcevic et al., 2014; Steinhorst & Klöckner, 2018; Zeiske et al., 2021). This type of incentive might at first lead to an increase in the target behavior, but as shown by numerous research studies, when the monetary incentives are removed, the behavior returns to baseline (Bolderdijk & Steg, 2015; Bolderdijk et al., 2011; Maki et al., 2016; Kaiser et al., 2020; Van Der Linden, 2015). A second effect of monetary incentives is the possibility of the crowding effect (Frey, 1994): if people become accustomed to enacting a behavior (such as pro-environmental behavior) solely to receive a reward, it will undermine intrinsic motivation and the feeling of moral commitment attached to the action (Bolderdijk & Steg, 2015; Gneezy et al., 2011), explaining the lack of effectiveness of monetary rewards over the long term (Van Der Linden, 2015). In a study by Zeiske and colleagues (2021), the incentive for using public transportation to work (i.

e., a card for the free use of public transportation for three weeks) had an effect only for the duration of the incentive; after the three weeks had passed, most participants returned to regular use of their private cars. In addition to monetary incentives, other studies have highlighted the importance of instrumental motives in promoting pro-environmental behaviors, such as saving time and improving physical and mental health (Steg, 2005). Two recent studies (Manca et al., 2022; 2023) have confirmed the importance of instrumental reasons in choosing public transportation rather than private cars. The former was generally considered safer, less expensive, and more convenient regarding the use of time. In particular, health-related motivations and momentary savings positively affected attitude and intention to use public transportation.

1.4. Persuasive technologies for sustainable mobility

The term "persuasive technology" encompasses technology designed to influence users' attitudes or behaviors through persuasion and social influence rather than coercion (Fogg, 2003). Persuasive systems dedicated to behavior change are actively studied within personal mobility, resulting in numerous systems and implementations that motivate users to make more eco-conscious decisions. These approaches have employed various strategies, including behavior feedback, social comparison, goal-setting, gamification, personalized suggestions, and challenges (Anagnostopoulou et al., 2018). These strategies have been continuously evolving, and new ones are consistently emerging. Furthermore, the implementation details, such as mobile trip planner apps versus web-based systems,

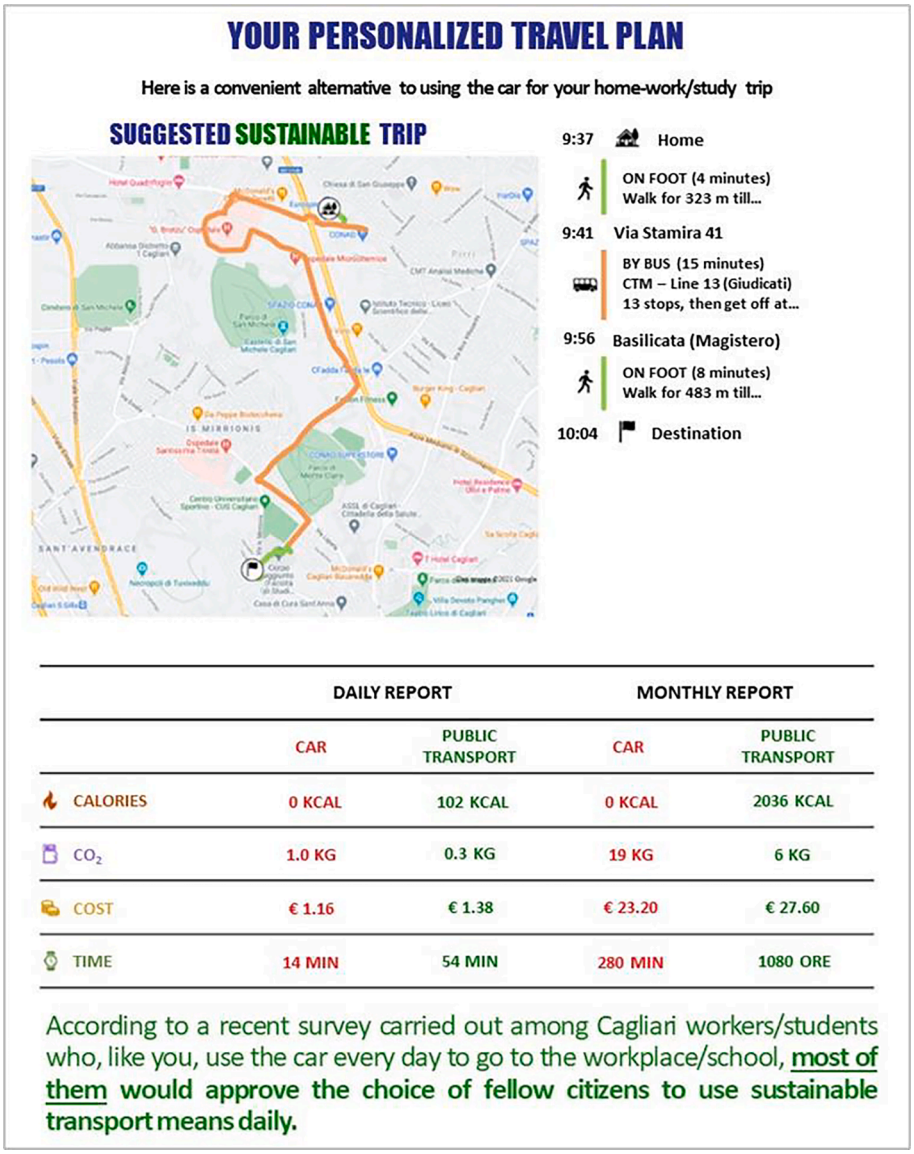

Fig. 1. An example of the Personalized Travel Plan (PTP) (see Giubergia et al., 2023).

vary significantly. Additionally, the transportation context, encompassing available infrastructure, alternative travel options, and costs related to different modes of transportation, are all influenced by the specific region, leading to substantial variations. The prevailing persuasive technique reported by Anagnostopoulou and colleagues (2018) in a recent review is self-monitoring, mainly employing visual feedback, often illustrating CO_2 emissions resulting from users' travel (Jariyasunant et al., 2015; Meloni et al., 2014; Bothos et al., 2014). Adopting sustainable and active transportation modes reduces mobility costs and increases calories expenditure; for this reason, some strategies additionally visualize costs and calories burnt (Meloni et al., 2014), calculated based on user mobility patterns. Visual feedback is frequently integrated with other persuasive strategies, such as goal-setting, challenges, social comparison, gamification, rewards, and personalized messages, enhancing its impact.

2. Method

2.1. Calculation of annual frequencies

According to Giubergia et al. (2023), regarding the calculation of annual frequency, in the questionnaire, the frequency of travel was asked as follows:

"Please indicate, on average, how often you travel to your place of work/study:

- Rarely: a few times a year (indicate in the box below the number of times in a year).
- Sometimes: a few times a month (indicate the number of times in a month in the box below).
- Often: several times a week (indicate the number of times in a week in the box below)".

For those who indicated "Rarely" the annual frequency was equal to the stated yearly frequency. For those who have indicated "Sometimes", the yearly frequency has been set equal to the stated monthly frequency multiplied by 11. For those who indicated "Often" the annual frequency was set equal to the weekly frequency multiplied by 4 and then by 11. It can be easily guessed that 11 is the number of working months per year, while 4 is the number of weeks in a month. The number of working months per year was placed equal to 11 because, when multiplied by 4 working weeks, this yields a number of working days equal to 220, which is equal to the number of working days for most workers.

Subsequently, the car drivers, the target of the intervention under consideration, were identified. The travel alternatives were elaborated for each participant, the feedback associated with the sustainable alternative and the private vehicle (car) was calculated, and the persuasive messages to be included in the Personalized Travel Plan (Fig. 1) were defined.

As reported in Fig. 1, an aspect that may have influenced the propensity to change means of transport is the difference in terms of time, cost, CO_2 emissions, and kilocalories burnt (PTP features) between trips made by private vehicles and the sustainable alternative. To analyze the influence of PTP components on the phenomenon analyzed, i.e., the Sustainable Travel Choice (STC), the difference between the total monthly travel time with the car and that with the sustainable alternative, the difference between the total monthly cost with the private car and that with the sustainable alternative, the difference between the total monthly CO_2 emissions with the private car and that with the sustainable alternative and the difference between the total monthly kcal consumed with the private car and that with the sustainable alternative were calculated for each individual. Specifically: Δkcal = kcal consumed with the car – kcal consumed with ST; ΔTime = Time spent with the car – Time spent with ST; ΔCost = Cost spent with the car – Cost spent with ST; Δ CO_2Emissions = CO_2 with the car – CO_2 with ST.

2.2. Travel alternatives modes calculation

According to Giubergia et al. (2023), Travel Alternatives Modes were processed using Google's API, particularly Google Maps Directions API. For the elaboration of the sustainable alternative to suggest, the following choices were made:

- Walking was proposed for individuals with commuting distances up to 2 km. This threshold reflects findings in the literature (Keijer & Rietveld, 2000; Chillón et al., 2016) showing that most commuting trips fall within this distance.
- The bicycle alternative was offered only to individuals who reported owning a bicycle and whose commuting distances were up to 5 km with an average uphill slope (back and forth route) of 2.5 % or less. The 5 km distance threshold aligns with the median cycling distance for commuting purposes reported in the literature (Hansen & Nielsen, 2014; Nordengen et al., 2019; Banerjee et al., 2022). The 2.5 % slope threshold is also supported by existing research (Broach et al., 2012; Wysling & Purves, 2022).
- The bus alternative was offered to everyone else.

Considering the walking and biking alternatives, the minimum time routes were chosen among the different available routes. Regarding the bike, the minimum time route may not coincide with the minimum distance route since Google's algorithm also considers the presence of slopes.

The travel alternatives were processed using Google's API, particularly Google Maps Directions API.

The questionnaire containing the suggested travel alternative, related feedback, and persuasive message was sent via a platform named Wofoo to individuals who reported using a car for their home-work/study commute.

Once the Personalized Travel Plan was displayed, each participant had to answer the following question, which is our final Dependent Variable (STC):

"Based on what you have just read, please answer the following question:

- I choose the sustainable alternative recommended by the PTP.
- I choose the car.
- Neither".

2.3. Experimental procedure

Referring to the work of Giubergia et al. (2023), the data collection process of the 398 participants involved different steps (Table 1). Within the framework of a Voluntary Travel Behavior Change program planned for the metropolitan city of Cagliari, during the period October 2019-January 2020, we contacted potential participants in the program. Specifically, we did it by sending emails to staff and students at the University of Cagliari, the Regional Government of Sardinia, and the Municipality of Cagliari. A generalized promotional campaign was also conducted, including advertisements on local TV channels and radio stations, posters displayed at bus stops, and postcards distributed at community centers. Each contacted individual was asked to complete a questionnaire about their travel behavior (time T0). This campaign resulted in 4,616 completed questionnaires, from which we identified 1,856 car commuters. Due to the COVID-19 pandemic, we had to stop the program. In October 2020, believing that the pandemic was under control, we conducted a second survey (time T1) asking about travel behavior and including some questions concerning socio-psychological dimensions (see 3.2.3). We contacted all participants from the first wave survey, including the 1,856 car drivers. Using the information collected at time T1, we constructed a Personalized Travel Plan for each individual. This plan included a description of a personalized sustainable travel option they could use for commuting trips. We calculated feedback metrics for both the sustainable alternative and the private car options. Then, from March 2021 to May 2021, we sent an email to all 1,856 car drivers (time T2). In the email, they were asked to choose, after being exposed to the experimental manipulation (Personalized Travel Plan), among three different travel alternatives for their commuting trips: 1) use of the car, 2) use of sustainable transport, 3) choice to not use neither car nor sustainable means of transport. A total of 467 individuals responded to both this questionnaire and the October 2020 survey. However, we excluded from the sample the people who did not choose the suggested sustainable means of transport and the car because they didn't travel for work or study (for group-level sample descriptives see Table 1 in the Appendix).

For the project, home and work addresses were geo-coded, annual frequencies for the home-work itinerary were calculated, the mode of transportation for this itinerary was verified, and the type of motor vehicle used, if any, was examined. Subsequently, the car drivers, the target of the intervention under consideration, were identified. In addition to this, the questionnaire that will be described later was administered (Giubergia et al., 2023).

2.4. Measures

The questionnaire administered at T1 contained the following questionnaires:

Intention to Use Sustainable Transport, 3 items (Piras et al., 2021). Intention to use sustainable transport was measured through items such as "In the next two weeks, I will mainly use the car for my trips"; "In the next two weeks, I will use public transport (bus, light rail, *etc.*) to get around town"; "In the next two weeks, I will use active mobility (walking, cycling) to get around town". Respondents rated each item using a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The reliability of the measure is the following: $\alpha = 0.66$.

Attitude toward the Use of Sustainable Transport, 3 items (adapted from Carrus et al., 2008). This was measured through three statements: "For me, using sustainable transport is Good", "For me, using sustainable transport is Useful", and "For me, using sustainable transport is Right". These were rated on a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The reliability of the measure is the following: $\alpha = 0.77$.

Perceived Behavioral Control, 3 items (adapted from Piras et al., 2021). Perceived Behavioral Control (PBC) was measured through three statements: "It would be easy for me to use sustainable transportation", "I am sure I can use sustainable transportation over the next week", "Using sustainable transportation is impossible for me". These were rated on a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The reliability of the measure is the following: $\alpha = 0.82$.

Social Norms, 2 items (adapted from Fornara et al., 2016). Social Norms were measured through two statements: "Most people I know think I should use sustainable transportation instead of the private car", and "Most people I know use sustainable transportation

Table 1
Representation of work phases.

STEP 1 (October 2019 – January 2020) – T0
Delivery of a first questionnaire measuring travel behavior to identify the target population (1.856 car drivers)
STEP 2 (October 2020 – November 2020) – T1
Delivery of a second questionnaire to the target population to unveil behavioral patterns and psycho-social characteristics
STEP 3
Construction of a Personalized Travel Plan (PTP) for each individual in the target population
[2]**STEP 4 (March 2021 – May 2021) – T2**
Delivery of the PTP to each individual in the target population and of a question measuring the intention to use the alternative proposed in the PTP, or the Sustainable Transport Choice

instead of the private car". Respondents rated each item using a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The two items were correlated positively: r = . 42.

Moral Norm, 1 item (adapted from Fornara et al., 2016). Moral Norm was assessed through one statement: "I feel morally obligated to use sustainable transportation regardless of what others do". Respondents rated each item using a 5-point Likert scale (0 = not at all likely, 5 = extremely likely).

Ascription of Responsibility, 2 items (adapted from Piras et al., 2021) Ascription of responsibility was measured through 2 items: "I feel personally responsible for the environmental problems that may result from the choice of my mode of transport" and "I feel personally responsible for the problems related to traffic, space occupation, and road incidentality in my city." Respondents rated each item using a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The two items were correlated positively: r = . 61.

Awareness of Ecological Consequences, 2 items (adapted from Piras et al., 2021) Awareness of ecological consequences was measured through 2 items: "I am aware that car use causes damage to the environment and people's health, and "I am aware that I can personally contribute (by using my car less for my trips) to improve the environment". Respondents rated each item using a 5-point Likert scale (0 = not at all likely, 5 = extremely likely). The two items were correlated positively: r = .58.

Sociodemographic Variables (i.e., gender, age, education level, profession, city of residence, driver's license, car ownership, number of cars per household, bicycle ownership) were also measured.

At T2, participants answered only one question:

"Based on what you have just read, please answer the following question:

– I choose the sustainable alternative recommended by the PTP;
– I choose the car;
– Neither".

2.5. Data analysis

Descriptive statistics and zero-order correlations among the investigated variables were calculated. Then, structural equation modeling (SEM) was applied to test a path analysis model using the "lavaan" package for R (Rosseel, 2012). The model depicted in Fig. 2 was fitted using diagonally weighted least squares because all variables were ordered categorical (DWLS). DWLS, unlike Maximum Likelihood, makes no distributional assumptions and is unaffected by biases caused using ordinal rather than continuous response scales (Rhemtulla et al., 2012). The Comparative Fit Index (CFI), Tucker–Lewis index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) were used to assess model fit. A CFI and TLI value greater than 0.95 indicate a good fit, with a value greater than 0.90 considered acceptable; a good fit is supported by RMSEA and SRMR values of less than 0.06 and 0.08, respectively (Schermelleh-Engel et al., 2003). The model chi-square, indicating misfit if it turns out statistically significant, is no longer used as a criterion for acceptance or rejection. Instead, the RMSEA close-fit test can be relied upon for assessing model fit. A p-value over 0.10 for this test indicates a good fit and a value between 0.05 and 0.10 indicates an acceptable fit.

The figure shows that the model included four exogenous variables linked to individual attitudes and beliefs: Awareness of Consequences, Ascription of Responsibility, Descriptive Norm, and Injunctive Norm. Because research participants received information

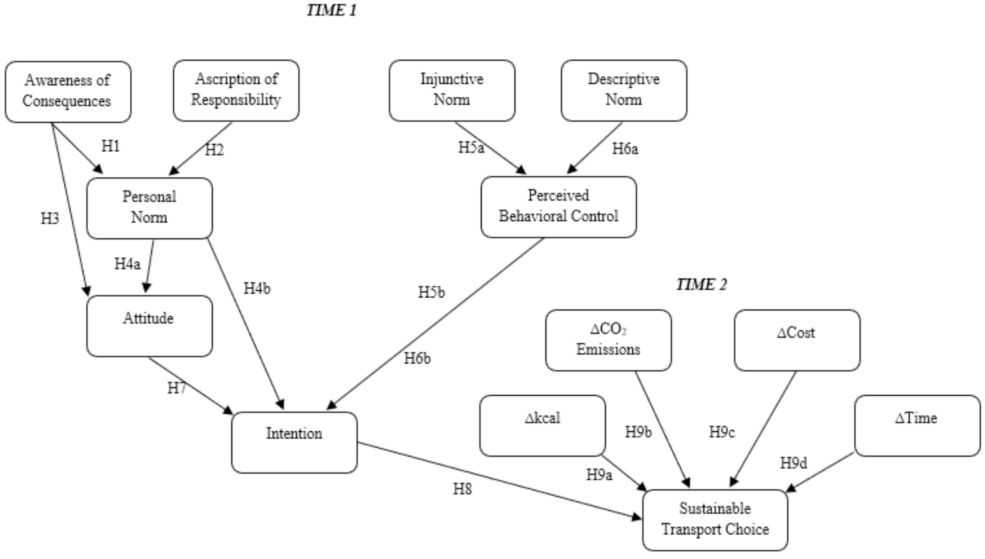

Fig. 2. Theoretical model.

regarding the benefits of using a sustainable alternative in ΔkcaI, ΔCO2, ΔCost, and ΔTime, four endogenous variables linked to information provided to research participants were included in the model. These variables were obtained as difference scores between sustainable alternatives and car use estimates provided to the participants. For example, if the sustainable alternative implied a travel time of 1 h, while the car implied a travel time of 30 min, the corresponding difference score was 1 h – 30 min = +30 min. Conversely, −30 min indicated that using the car implied a longer travel time. The exogenous focal variable in the model was Sustainable Transport Choice (STC), a dummy variable reflecting the participant's choice (keep using the car = 0; switch to public transportation = 1). Other exogenous variables modeled the psychological processes likely to predict the participant choice on the model's attitudes and beliefs side. In keeping with NAM elements, we hypothesized that Sustainable Transport Choice was predicted by Awareness of Consequences, Ascription of responsibility through Moral Norm, Attitude toward the use of sustainable transport, and Intention to use sustainable transport. Consistently with the TPB framework, we hypothesized that Moral Norm, Perceived Behavioral Control, Attitude toward sustainable transport, and Intention to use sustainable transport predicted Sustainable Transport Choice. Indirect effects supporting each of the two theories were tested using bias-corrected bootstrapped CIs obtained from 5,000 bootstrap iterations of the model. The partially standardized indirect effect reflects the average increase in switching to public transportation accounted for by the mediators for a unit change in the exogenous variables. Large, medium, and small effect size thresholds are 0.26, 0.13, and 0.02, respectively (Hayes & Rockwood, 2017).

Based on previous studies, our research hypotheses are as follows:

H1: Awareness of Consequences has a positive impact on Personal Norm (in accordance with NAM).
H2: Ascription of Responsibility has a positive impact on Personal Norm (in accordance with NAM).
H3: Awareness of Consequences has a positive impact on Attitude.

Table 2
Sample's socio-demographics.

Variables	Total			
	N	**%**	***M***	***SD***
Gender				
Women	193	48.5	–	–
Men	205	51.5	–	–
Total	398	100	–	–
Age				
18–30	76	19.1	–	–
31–40	72	18.1	–	–
41–60	231	58	–	–
Over 60	19	4.8	–	–
Educational level				
Graduate	245	61.6	–	–
Not graduate	153	38.4	–	–
Monthly income				
0 – 500€	46	11.6	–	–
501 – 1000€	25	6.3	–	–
1001 – 1500€	116	29.1	–	–
1501 – 2000€	121	30.4	–	–
2000 – 3000€	58	14.6	–	–
> 3000€	32	8	–	–
Student	64	16.1	–	–
Not Student	334	83.9	–	–
Number of cars per household	398	100	1.88	0.74
1	115	28.9	–	–
2	235	59	–	–
3	33	8.3	–	–
4	12	3	–	–
5	3	0.8	–	–
Household composition	398	100	2.88	1.20
1	57	14.3	–	–
2	99	24.9	–	–
3	107	26.9	–	–
4	112	28.1	–	–
5	16	4	–	–
6	6	1.5	–	–
7	1	0.3	–	–
Residence area				
Municipality of Cagliari	197	49.5	–	–
Metropolitan City of Cagliari	146	36.7	–	–
Other	55	13.8	–	–

Note. N = 398. Participants were on average 43.29 years old (min: 19; max = 70; *SD* = 11.65). *M* = Mean; *SD* = Standard Deviation.

H4: Personal Norm has a positive impact on both Attitude (H4a) and the Intention to use Sustainable Transport (in accordance with NAM and VBN).
H5: Injunctive Norm has a positive impact on Perceived Behavioral Control (H5a) and this latter has in turn a positive impact on the Intention to use Sustainable Transport (H5b) (in accordance with the extended version of the VBN, Fornara et al., 2020).
H6: Descriptive Norm has a positive impact on Perceived Behavioral Control (H6a) and this latter has in turn a positive impact on the Intention to use Sustainable Transport (H6b) (in accordance with the extended version of the VBN, Fornara et al., 2020).
H7: Positive Attitude toward Sustainable Transport has a positive impact on the Intention to use Sustainable Transport.
H8: Intention to use Sustainable Transport has a positive relation with Sustainable Transport Choice.
H9. The delivery of personalized feedback relating to the use of Sustainable Transport may have a) a negative or null effect on the intention to use a car vs. Sustainable Transport and b) a positive or null effect on the intention to use a car vs Sustainable Transport. H9a refers to monthly information about kcal consumption, H9b refers to monthly information about CO2 emissions, H9c refers to monthly information about Costs and H9d refers to monthly information about Time spent traveling.

2.6. Participants

The final database consisted of 398 participants (see 2.3 for the sample selection process), with an age ranging from 19 to 70 years ($M = 43.29$, $sd = 11.65$). Table 2 shows the sample's socio-demographic features. The entire sample was resident in Sardinia (Italy), of which 197 (49.5 %) resided in the municipality of Cagliari, 146 (36.7 %) in municipalities within the Cagliari metropolitan area, and 55 (13.8 %) in neighboring municipalities outside the metropolitan area. Males were 205 (51.5 % of the sample). 245 (61.6 %) were graduates, and only 16.1 % of the sample were students. As the participants were all car users, 87.9 percent of them had one (28.9 %) or two (59 %) cars available in their household. The participants' households were quite heterogeneous, with only 57 subjects (14.3 %) reporting that they lived alone, 79.9 % cohabiting between 1 and 3 people, and the remaining 5.8 % with four or more people. Note that our sample is not representative of the working and studying population of Cagliari in terms of gender (males: 52 % in our sample vs 47 % in Cagliari), age (30–60 age group: 76 % in our sample vs 84 % in Cagliari), and the number of household members (average 2.9 in the sample vs 1.9 in Cagliari). This difference can be attributed to the fact that, for our analysis, we are considering only individuals who at the time of the experiment used to commute by car.

3. Results

3.1. Descriptive statistics and correlations

We have calculated means, standard deviations, alphas, skewness, kurtosis, and zero-order correlations between variables (see Table 2 in the Appendix). The analyses showed that the variables assume a tendentially normal distribution, and there is no multicollinearity among the investigated variables ($r < 0.70$).

3.1.1. Personalized travel Plan

Table 3 shows the average values of the feedback provided to respondents before choosing between continuing with the private car

Table 3
Means and standard deviations of monthly PTP messages.

		M	SD
Car (N = 398)	Monthly kcal	/	/
	Monthly Cost	77,57	81,28
	Monthly Time	669,92	424,19
	Monthly CO_2 Emissions	67,48	73,43
Public Transport (N = 320)	Monthly kcal	2.350,45	1.845,66
	Monthly Cost	41	25,12
	Monthly Time	1.855,57	947,78
	Monthly CO_2 Emissions	32,07	41,82
Walking (N = 32)	Monthly kcal	4.010,06	2.160,72
	Monthly Cost	/	/
	Monthly Time	761,75	376,14
	Monthly CO_2 Emissions	/	/
Bicycle (N = 46)	Monthly kcal	4.419,31	1.718,67
	Monthly Cost	/	/
	Monthly Time	581,04	236,73
	Monthly CO_2 Emissions	/	/

Note. M = Mean; SD = Standard Deviation.

or choosing the sustainable alternative.

The private car is less convenient in terms of cost than the sustainable alternatives. On the other hand, the car is more advantageous in terms of travel time than the sustainable alternatives. The analysis of the feedback associated with travel time shows that the longest duration is for public transport, while the shortest is for cycling. This is because active mobility (walking or cycling) was recommended for shorter trips. Finally, the sustainable alternative is advantageous, compared to the private car, in terms of kilocalories burned and CO_2 emissions. Table 4 shows the final choices made by the participants.

3.2. Structural Equation modeling (SEM)

Although the model was statistically significant on the chi-square test ($\chi^2 = 100.82$; df = 48; $p < 0.001$), the CFI = 0.951 and TLI = 0.927 were above the good and acceptable thresholds. The SRMR = 0.056 and RMSEA = 0.053 indicated a good fit according to conventional standards. Noteworthy, the p-value for the RMSEA close-fit test was 0.362, thus supporting the good model fit. As shown in Fig. 3, Δkcal and ΔTime predicted Sustainable Transport Choices significantly. The greater the difference between Δkcal consumed using the sustainable alternative relative to car use, the greater the tendency to switch to the sustainable alternative (public transportation). Conversely, the higher the difference between ΔTime using the sustainable alternative relative to car use, the lower the tendency to switch to the sustainable alternative (public transportation). Intention to use sustainable transport was the single best predictor of Sustainable Transport Choice. The predictor set collectively accounted for about 30 % of the variance in Sustainable Transport Choice ($R^2 = 0.29$). Next, we examined the predictors' differential weight on the Intention to use sustainable transport. Perceived behavioral control and Moral Norm were linked to greater Intention to use sustainable transport, with Perceived Behavioral Control being the single best predictor. The model also hypothesized that Attitude toward the use of sustainable transport was associated with the Intention to use sustainable transport, but the path coefficient, albeit significant, was quite small. Taken together, the model accounted for about 30 % of the variance in the Intention to use sustainable transport ($R^2 = 0.32$).

According to the NAM framework, Sustainable Transport Choice is predicted by Awareness of consequences and Ascription of Responsibility through Moral Norm, then by Attitude toward the use of sustainable transport, and lastly, by the Intention to use sustainable transport. The analysis of indirect effects (Table 5) revealed that this pathway to using a sustainable alternative was barely significant and feeble at best. We identified the weaker link in the relationship between Attitude toward the use of sustainable transport and Intention to use sustainable transport. So, we tested another pathway to Sustainable Transport Choice involving Awareness of Consequences and Ascription of responsibility through Moral Norm, and Intention to use sustainable transport. In other terms, we partialled out the contribution of Attitude toward the use of sustainable transport. The corresponding indirect effects were statistically significant with an effect size in the small-medium range. According to the TPB framework, we hypothesized that Sustainable Transport Choice was predicted by Descriptive Norm and Injunctive Norm, Perceived Behavioral Control, Attitude toward the use of sustainable transport, and Intention to use sustainable transport. The analysis of indirect effects (Table 5) revealed that this pathway to using a sustainable alternative was barely significant, and at best very weak. Again, the link in the relationship between Attitude toward the use of sustainable transport and the Intention to use sustainable transport was so small as to dampen the indirect effects. For this reason, we tested a new pathway to Sustainable Transport Choice involving Descriptive Norm and Injunctive Norm through Perceived Behavioral Control and Intention to use sustainable transport. The corresponding indirect effects were statistically significant with an effect size in the small-medium range. The largest effect size was the one of the pathway linking Descriptive Norm to Sustainable Transport Choice through Perceived Behavioral Control.

4. Discussion

One of the aims of the research was to analyze which socio-psychological variables might influence the intention to use a sustainable transportation alternative to the private car. To this end, an attempt was made to integrate the main theories used in the study of pro-environmental behavior, namely the Norm Activation Model (NAM), the Theory of Planned Behavior (TPB), and the Value-Belief-Norm theory with its subsequent extensions (e.g., Fornara et al., 2020), into the analysis model. The subsequent research hypotheses were all confirmed by the Structural Equation Model. In line with the Norms Activation Model (NAM; Schwartz, 1977), awareness of ecological consequences related to private car use and ascription of responsibility were confirmed to be excellent predictors of personal norms activation, confirming H1 and H2, respectively. Specifically, concerning H1, the results confirm previous studies on the link of awareness of the environmental consequences of a given behavior on personal norms, as found in both for other

Table 4
The final choice of transport mode.

PTP	N	Choice	N	%
Public Transport	320	Car	228	71.3
		PT	92	28.8
Walking	32	Car	11	34.4
		Walking	21	65.6
Bicycle	46	Car	20	43.5
		Bicycle	26	56.5

Note: PT = Public Transport.

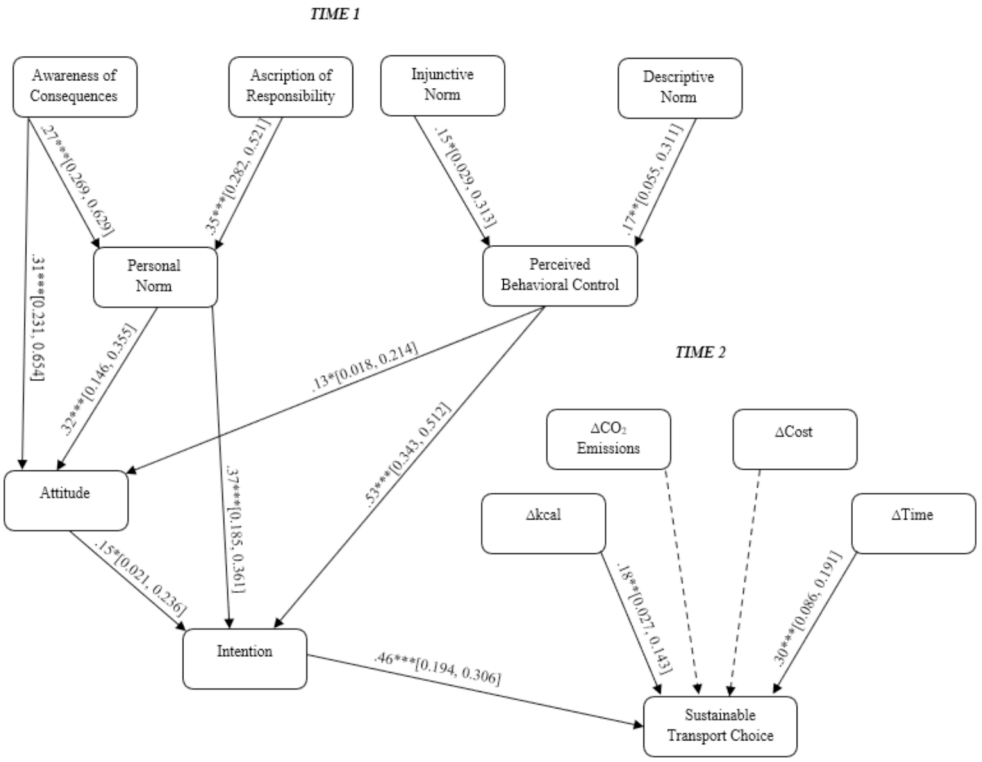

Fig. 3. Structural Equation Model. *Note:* * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Table 5
Indirect effects.

	Estimate	BootSE	z	P(>|z|)	BootLLCI	BootULCI	Std.lv	Std.all
NAM								
Awareness → Moral Norm →Attitude →STC	0.00	0.00	1.96	0.05	0.00	0.01	0.004	0.006
Ascript_Resp → Moral Norm →Attitude →STC	0.00	0.00	1.87	0.06	0.00	0.01	0.003	0.007
Awareness →Moral Norm →STC	0.03	0.01	3.46	0.00	0.02	0.05	0.03	0.046
Ascript_Resp → Moral Norm →STC	0.03	0.01	3.55	0.00	0.01	0.04	0.027	0.059
TPB								
Descriptive Norm→ PBC →Attitude →STC	0.00	0.00	1.94	0.05	0.00	0.00	0.002	0.003
Injunctive Norm →PBC →Attitude →STC	0.00	0.00	1.77	0.08	0.00	0.00	0.001	0.001
Descriptive Norm →PBC →STC	0.04	0.01	4.72	0.00	0.03	0.06	0.043	0.085
Injunctive Norm→PBC→STC	0.02	0.01	2.19	0.03	0.00	0.04	0.019	0.037

Note: STC = Sustainable Travel Choice; Ascript Resp = Ascription of Responsibility; PBC = Perceived Behavioral Control; Std.lv = Partially standardized indirect effect.

environmental behaviors (i.e., household energy efficiency; Fornara et al., 2016), and private car use: indeed, in Nordlund and Garvill's (2003) study, awareness of specific consequences related to car use (i.e., car traffic as cause of environmental problems and degree of seriousness of car-induced problems) directly influenced personal norms and, consequently, willingness to cooperate by reduced personal car use. In line with the broader objective of the study regarding the theoretical framework of Value-Belief-Norm (VBN), the results obtained provide further corroboration to previous work focused on encouraging sustainable choices in travel modes (Lind et al., 2015). This study determined that personal norms were directly influenced by recognition of environmental consequences and attribution of responsibility. Thus, the decision to adopt environmentally friendly transportation methods is influenced by increased awareness of responsibility for ecological issues related to the use of private motorized transportation options and self-attribution of responsibility for choice, which, in turn, reinforce personal norms that guide the choice of environmentally friendly travel alternatives. Concerning the NAM and VBN, these personal norms positively influenced both attitudes related to

sustainable transportation (H4a) and the intention to use these modes of transportation as an alternative to the private car (H4b), confirming the fourth research hypothesis (H4). Regarding the social context and normative influence, both the perception of how behavior is approved/disapproved (i.e., injunctive norms) and the actual behavior of significant others (i.e., descriptive norms) positively influenced the perceived behavioral control related to the use of sustainable transportation, confirming, in line with the extended VBN, hypotheses H5a, and H5b, respectively. The results thus confirm the importance of normative influence in promoting individual pro-environmental behaviors (Cialdini & Jacobson, 2021), extending the results to sustainable mobility behaviors. Interestingly, the "boomerang effect" described by Gardner and Abraham (2010) did not emerge in the study; in this case, participants were more likely to adapt to social influence, both in terms of what was being endorsed and the behavior of others. The effect of social norms on perceived behavioral control confirms previous results based on the extended VBN model about household waste separation disposal for descriptive norm (Fornara et al., 2011) and pro-biodiversity action for injunctive norm (Fornara et al., 2020). Finally, integrating the pathways hypothesized by TBP (Ajzen, 1985; Ajzen & Fishbein, 1980), attitude toward sustainable transportation, influenced by socio-psychological variables, at T1, proved to be the best predictor of behavioral intention, confirming hypothesis H7. At T2 this behavioral intention positively influenced the actual behavior, represented by the choice to use sustainable transportation (H8). An additional aim of the research was to verify the impact of the PTP, specifically the effects of different feedback types (travel time, travel cost, CO_2 emissions, and kcal consumption) on the intention to change travel behavior from private vehicles to more sustainable means of transportation. The model estimation results confirm hypothesis H9a. Specifically, it was found that the difference in kcal consumption between the proposed alternative and the car alternative positively influences the choice to use sustainable transportation. This result contrasts with past research (di Teulada et al., 2014; Esztergár-Kiss & Lizarraga, 2021; Piras et al., 2018), which found that kcal consumption was among the least important feedback factors considered by users. However, this can be explained by the fact that for some users, the proposed alternative involved active mobility, making the difference in the value of this feedback, compared to the car alternative, more apparent. In contrast, the parameter associated with the difference in CO_2 emissions was not significant, differing from the findings of Sottile et al. (2017), primarily due to its multicollinearity with the travel time variable. Regarding hypothesis H9b, model results clearly indicate that the travel time difference negatively impacts the choice to use sustainable transportation, confirming the results of past research (di Teulada et al., 2014; Sottile et al., 2017). At the same time, the coefficient associated with the difference in travel cost was not statistically significant. As explained by Giubergia et al. (2024), this finding can be attributed to the low variability in travel cost information, which was zero for individuals with active mobility travel plans and equivalent to the cost of a public transport subscription for individuals with a transit alternative.

5. Conclusions

In conclusion, this study's results shed light on several important variables that influence the adoption of sustainable transport options. The most important predictor among the socio-psychological variables of the transition to sustainable transport choices over time was the intention to use sustainable transport, which emerged as the most influential factor. The importance of effective and time-saving choices in promoting sustainable mobility was also highlighted. Time constraints were found to be a barrier to the adoption of sustainable alternatives. Interestingly, those who consumed more calories were more likely to choose greener options, suggesting a possible link between health concerns and green transport choices. The results highlight the importance of individual perceptions and personal values in influencing travel decisions, showing that perceived behavioral control and personal norm are the main determinants of intention to use sustainable transport. In addition, the moral norm was found to act as a mediator, allowing ascription of responsibility and awareness of consequences to influence intention indirectly. Furthermore, both descriptive and injunctive norms influenced intention through perceived behavioral control, demonstrating the importance of social norms and perceived behavioral control in promoting sustainable travel practices. These findings provide valuable insights into the socio-psychological factors that influence travel choices and pave the way for the development of our application. Our study, and in particular the result concerning the effect of travel feedback, offers valuable insights for guiding policymakers to encourage car drivers to change their travel behavior towards more sustainable options. Firstly, we observed that the difference in travel time between the car and the proposed alternative influenced the choice of using either option. This finding aligns with previous research, suggesting that behavioral interventions alone may not be sufficient. Structural measures that improve the service level of sustainable alternatives are also needed. Another important result concerns calorie feedback. From a policy standpoint, this suggests that health initiatives promoting the health benefits of active travel choices like cycling and walking can contribute to behavior change. These interventions can be targeted toward individuals who prioritize health and fitness.

The study is not without its limitations: as mentioned earlier, the T1 phase of the study was conducted in October 2020, a month in which a peak in COVID-19 incidence was reached. This situation mandated the exclusion of all participants who were not traveling for study or work purposes. A limitation associated with the Personalized Travel Plan could be its frequency, because it was delivered only one time. Previous studies have shown that repeating regulatory framing over time has a more significant impact than a single message (Carfora et al., 2022) so adopting period messaging might be beneficial. Mobile applications offer new possibilities in an endeavor to promote sustainable mobility. A variety of persuasive mobile apps (Fogg, 2002) are currently available (Cellina et al., 2019). However, their efficacy in changing mobility behavior is unclear. Sunio and Schmöcker's (2017, p. 553) *meta*-analysis reports that "methodologically robust studies are largely missing". Cellina and colleagues (2019) recently published the first randomized controlled trial on the topic, but the authors point out some limitations of their study: obtrusive tracking, severe sample attrition, and a potentially unrepresentative sample. Finally, our study also has some limitations related to the sample size. First, the sample was relatively small and not representative of the entire population of the Cagliari metropolitan area, as it primarily consisted of students and public employees who commuted by car. This limitation restricts the generalizability of our results. For example, individuals with constraints

that the sample population may not have faced could potentially react differently to the proposed alternative and its feedback. The second limitation concerns self-selection within the sample. Due to a high attrition rate between survey waves, only 398 individuals out of an initial pool of 1,856 car drivers participated in the final analysis. This suggests that the individuals who participated in the last survey may have been more motivated and environmentally conscious than the general population, potentially biasing the effectiveness of the Personalized Travel Plan. Despite these limitations and the issue of generalizability, we believe our findings contribute valuable insights to the growing field of travel behavior change through soft interventions.

CRediT authorship contribution statement

Oriana Mosca: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Marco Lauriola:** Writing – review & editing, Writing – original draft, Formal analysis. **Andrea Manunza:** Writing – review & editing, Writing – original draft. **Alessandro Lorenzo Mura:** Writing – review & editing, Writing – original draft. **Francesco Piras:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Eleonora Sottile:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Italo Meloni:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **Ferdinando Fornara:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, 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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2024.06.027.

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