RESEARCH-ARTICLE

On Attitudes, Norms, Control Beliefs and Interfaces: Why Sustainable Transport Adoption is not an HCI Problem

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Abstract

Promoting sustainable mobility requires technological innovation and changes in individual travel behavior. Using the Theory of Planned Behavior, we examined how attitudes, norms, and perceived control shape the willingness to adopt alternatives to car use. We designed 38 future commuting scenarios, each of which isolated a single dimension across three mobility concepts: public transportation, cycling, and shared automated vehicles. In an online survey (N = 168), participants rated their willingness to switch modes and pay more. To deepen our understanding, we conducted follow-up interviews (N = 10), exploring their everyday mobility practices and their likes and dislikes regarding the practicality of the future scenarios. Our findings show that features linked to instrumental attitudes and control beliefs elicit stronger intentions than affective cues, ecological appeals were less persuasive. We argue that effective behavior change depends on linking motivational factors to the realities of everyday mobility contexts.

CCS Concepts

• **Human-centered computing → User interface design**; **Scenario-based design**; **Empirical studies in interaction design**; • **Applied computing → Transportation**; • **Social and professional topics → User characteristics**.

Keywords

Sustainable mobility, mobility behavior, transportation, climate change, behavior change, sustainability, digital interventions, carbon emissions, behavioral intention, Theory of Planned Behavior

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1 Introduction

Climate change is one of the most pressing challenges of our time, with human mobility being a significant contributor to global CO_2 emissions. Transport contributes to air pollution, noise pollution, and habitat fragmentation, and is responsible for about a quarter of the EU's total greenhouse gas (GHG) emissions [1]. Mobility is both a necessity and a deeply ingrained aspect of daily life, whether it is commuting to work, running errands, or visiting loved ones. However, the way our current transportation systems are designed has long prioritized motorized individual transport. An article in The Atlantic [2] discusses data showing that countries like Italy, Germany, and France have higher per capita car ownership rates than the United States, contrary to the popular belief that Americans love cars and that the U.S. is closely associated with car culture. Coupled with broader societal trends toward individualization and private vehicle ownership, high rates of car ownership has resulted in not only high GHG emissions but also a host of social costs, including noise pollution, traffic congestion, and physical inactivity [9]. Despite the increased investment in sustainable transport infrastructure and digital tools, car use remains persistently high, especially in Western countries.

Changes in current mobility systems can significantly impact climate outcomes. Thus, our dependence on private vehicles and the freedom they afford to travel anytime, anywhere has far-reaching consequences for both the environment and society. Numerous efforts have sought to reduce car traffic and promote more sustainable transportation modes. The Agora Verkehrswende team [3] has outlined twelve theses for transforming Germany's transportation sector. They emphasize renewable fuels, infrastructure improvements, expanded rail freight, and advancing electromobility as key strategies for reducing GHG emissions [32]. Other countries are pursuing similar strategies. For instance, the *European Green Deal* aims to reduce transport-related emissions by 90%

[1]https://www.eea.europa.eu/en/topics/in-depth/transport-and-mobility
[2]https://www.theatlantic.com/international/archive/2012/08/its-official-western-europeans-have-more-cars-per-person-than-americans/261108/
[3]https://www.agora-verkehrswende.de/

by 2050 through initiatives that promote urban mobility planning, zero-emission public transport, and infrastructure for alternative fuels [29]. France's *Mobility Orientation Law (LOM)* supports shared mobility services and workplace travel plans [17].

Among these, digital innovations have emerged as promising tools for reshaping mobility practices. For example, mobile apps now enable flexible, eco-friendly options like last-mile solutions (e.g., e-scooters), offering new ways for people to organize their travel [33]. Mobility choices are not merely infrastructural or economic decisions, they are influenced by habits, values, and social expectations [48]. Without a corresponding shift in how individuals understand and engage with mobility, these solutions can yield counterproductive results, such as e-scooters replacing walking rather than supplementing public transit [36]. This highlights a crucial tension: technical advancements may backfire if integrated into daily routines without sustainability being a guiding principle. Thus, sustainable mobility requires more than just efficient technologies, it calls for broader lifestyle and behavior changes informed by an awareness of environmental impact.

In the field of human-computer interaction (HCI) research, a popular strategy is to use eco-feedback technology to provide users with information about their resource consumption and other sustainability-related habits [21]. Previous studies have shown that immersive virtual reality (VR) can address psychological needs, such as emotional connection, engagement, and perceived self-efficacy, in ways that may encourage sustainable behavior, however, this has typically only been observed in educational or emotionally resonant contexts [34, 58]. Yet many interventions aiming to promote sustainable mobility have had limited success [4]. One possible reason is that they often focus on short-term feedback strategies, such as nudging [10, 39], without addressing the contextual factors that shape long-term intentions and habits. Silberman et al. [52] observed that *"thus far, sustainable HCI research has had little impact outside HCI. Most early system-development efforts within Sustainable Human-Computer Interaction (SHCI) saw sustainability as an application domain for HCI business as usual"*. Thus, the HCI community wrestles with a deep existential question [13]: Is technology the answer? Baumer and Silberman [8] explicitly urged the community to *"develop a reflective awareness of situations in which computational technologies may be inappropriate."*

We systematically tested this question in the field of transportation. To better understand the drivers of sustainable mobility choices in the real world, we take a two-part research approach that bridges the gap between theory and real-world impact. First, we analyzed existing sustainable mobility concepts through the lens of the Theory of Planned Behavior (TPB) [1], identifying specific design themes aligned with each dimension of the model. Second, we conducted an online study to examine which TPB elements most significantly influence individuals' intentions to adopt sustainable mobility practices. Through a between-group vignette study [5] with car users in Europe, we assessed the relative persuasive power of each TPB dimension, deliberately including only car users to examine factors influencing those most reliant on private vehicles. To complement these findings and gain deeper insight into everyday travel practices and responses to vignette scenarios, we carried out follow-up interviews with ten participants from the same pool. By systematically aligning vignette scenario content with TPB dimensions, empirically testing their effects across mobility contexts, and triangulating results with qualitative insights, our study offers a novel mixed-method approach for evaluating psychological levers in sustainable transport design. This research provides the HCI community with empirical and theoretical insights into how psychological and contextual factors influence the effectiveness of ubiquitous technologies in shaping everyday mobility. Our findings show that sustainable mobility requires interventions that are ecologically embedded, linking digital persuasion with infrastructural and cultural realities, rather than relying solely on technological innovation.

2 Background and Related Work

We introduce the TPB as a suitable theoretical construct for analyzing behavioral intentions for mobility choices and discuss how technologies attempt to promote a shift in sustainable mobility.

2.1 Determinants of Intentions and Actions

Understanding what motivates individuals to change their behavior is a critical component in designing effective interventions for mobility-related behavior change. TPB provides a well-established psychological framework for predicting and explaining human behavior across a range of contexts [1]. According to TPB, an individual's intention to perform a particular behavior is the most immediate predictor of action. This intention is, in turn, influenced by three core components: *attitude* toward the behavior: the perceived value or outcome of performing it, *subjective norms:* perceived social pressure to perform or not perform the behavior, and *perceived behavioral control:* the perceived ease or difficulty of performing the behavior.

In the context of sustainable mobility, TPB and its three components have provided a theoretical framework used to explore how these components shape the understanding of individuals' behavioral intentions for engaging in specific mobility practices, such as the intention to use public transit, cycling, or carpooling instead of private vehicles [2, 7, 35, 42]. For example, a study by Haustein and Jensen [31] adapted the TPB to explore the intention to purchase or repurchase electric vehicles among both conventional and electric vehicle drivers. They showed that both affective factors, such as driving pleasure, and instrumental ones, such as driving range, serve as significant predictors of intention. Similarly, Caballero et al. [14] applied TPB to investigate students' intention to use the bicycle as a means of transportation. They showed that intentions were a predictor for 53% of actual bicycle use, with attitude and perceived behavioral control having slightly more influence than subjective norms. In another study, Sadeghian et al. [48] used TBP to analyze Reddit data and understand people's intentions for changing mobility practices towards more sustainable forms. They also found that attitudes and control beliefs are influential factors in choosing more sustainable means of transport.

Although several studies have confirmed the benefits of TPB in explaining the formation of behavioral intentions, there is still debate about its ability to predict actual behavior. For example, Schoenau and Mueller [50] explored the influence of psychological and environmental factors on the intention and actual choice to adopt sustainable mobility practices. They found that while attitudes play a central role in shaping mobility-related decisions, less deliberate factors, such as habits, influence actual behavior more strongly than intention alone. These results align with prior research by Verplanken et al. [55], which emphasizes the role of habitual processes in everyday mobility decisions. Similarly, Pronello et al. [47] suggests that the affective and subconscious mechanisms that are often overlooked in TPB-based approaches play an important role in shaping mobility behavior. Therefore, it is important to acknowledge the limitations of TBP in considering all determinant factors in individuals' mobility behavior. While previous work has critiqued TPB for not accounting for habits or emotional drivers, these critiques do not diminish its strength in explaining behavioral intentions. It provides a clear foundation for designing controlled interventions that target single behavioral constructs, making it well-suited for disentangling the relative persuasive impact of different design features.

2.2 Designing Technology for Sustainable Mobility

In the last decade, with the growing urgency of the climate crisis, various technologies with sustainability goals embedded in their design have been introduced. These include the widespread adoption of electric vehicles, as well as connected and automated driving systems that support cooperative strategies such as platooning, trajectory optimization, and signal-free intersection coordination to reduce fuel consumption and emissions [40, 41]. Driving automation further expands this vision by promising to optimize traffic flow and enable new forms of transportation that support more eco-friendly driving strategies [6, 25, 43]. In parallel, developments in in-vehicle interfaces, such as dynamic gesture recognition are reshaping how users interact with increasingly intelligent mobility systems, potentially enhancing the usability and sustainability of everyday travel [24].

Besides concepts that focus on automation, several researchers have focused on in-vehicle user interfaces that promote sustainable driving behavior. These user interface designs typically provide real-time or post-trip feedback on driving performance based on factors such as fuel efficiency, CO2 emissions, and optimal gear or speed recommendations [11, 27, 45]. However, a limitation of these vehicle-centric solutions is that they often fail to consider the broader context of individuals' mobility practices. For instance, while speed and gear optimization may support eco-driving in conventional vehicles, these parameters may become irrelevant as driving automation progresses. Therefore, future sustainable mobility should extend beyond driving feedback to consider how individuals make mobility choices in their daily practices. Without integrating sustainability goals into broader behavioral patterns, automation can even lead to private vehicle dependence and consequently increase congestion and pollution issues [15]. To address these limitations, several researchers proposed technologies that seek to influence individuals' overall mobility choices by deploying strategies such as feedback, self-monitoring, social comparison, nudging with a gamified approach, and goal-setting [3, 51]. For instance, applications such as UbiGreen [20] and Peacox [12] aim to reduce private car use by visualizing environmental impacts and nudging users toward more sustainable modes like public transport or walking. SUPERHUB [22] combines goal-setting, rewards, and community sharing to motivate long-term behavior change.

Researchers in urban informatics have long studied how data-driven systems influence participation, governance, and collective urban decision-making processes [18, 19]. Building on this, prior work in urban interaction design has employed participatory and data-centric approaches to tackle complex urban and environmental issues, such as climate adaptation and mobility transitions [30, 37]. Such issues are conceptualized as "wicked problems," emphasizing design-led interventions, visual tools, and cross-sector collaboration to navigate interdependent social, technical, and policy systems [38, 51, 53]. It is important to note that for technology to change people's mobility towards more sustainable forms, it should first be accepted and integrated into their everyday practices. This demands a fundamental understanding of the factors that shape individuals' intentions towards a specific behavior such as financial costs of these behavior changes [16] or the fulfillment of their psychological needs in the suggested form of mobility [28]. Prior work has emphasized that values, social norms, and personal identity are also critical in shaping mobility-related decisions [46]. A growing body of work on shared mobility highlights the need to address psychological barriers, such as perceived loss of control, safety concerns, or low confidence in service reliability-to support transitions away from private car use [54]. In addition, while many studies use frameworks such as the Technology Acceptance Model (TAM) or Social Cognitive Theory to predict adoption, integrated approaches, such as combining TPB with these models have proven effective in explaining behavioral adoption across domains [26]. This points to the need for more human-centered approaches that consider how mobility technologies interact with users' lived experiences and behaviors. Given the shortcomings identified, namely, a limited understanding of how specific behavioral drivers are represented in design, and challenges in isolating the persuasive effects of individual cues, we adopt a two-step research approach. First, we conduct an analysis of future-mobility design concepts to identify how TPB dimensions are conceptualized. Second, we use these insights to develop targeted scenarios and evaluate their persuasiveness in a vignette-based study.

3 Study 1: Analysis of Design Concepts

The *Reimagining Mobility* projects of the Industrial Design Engineering faculty at TU Delft [4] aim to support a more sustainable world by building concepts of mobility systems that use low-emission solutions and focus on reducing energy use, pollution, and congestion, while improving safety. We have filtered through the projects done as part of this course initiative and sorted the proposed concepts according to the TPB dimensions. Our goal was to bridge the gap between behavioral theory and design practice. We did so by examining how behavioral drivers from the TPB manifest in design representations of future mobility. Through our analysis, we sought to identify design-relevant cues, including features, narratives, and visual elements that reflect affective, instrumental, normative, and control-related motivations. These

[4] https://www.tudelft.nl/en/2024/ide/april/discover-the-21-reimagining-mobility-course-projects

insights informed the creation of vignette scenarios that isolated a single TPB dimension while remaining grounded in authentic design language.

3.1 Method

As shown in the examples in Figure 1, bachelor's degree students in Industrial Design Engineering at TU Delft have explored meaningful mobility from various angles and developed concepts for the future of mobility. The concept is presented in the form of a digital advertorial. We went through all the published projects for the last three years (2022, 2023, and 2024) [5]. The projects covered varied topics such as making mobility more seamless, sustainable, and user-centered, while exploring meaningful transportation futures through innovative concepts aimed at users, stakeholders, and society within the broader mobility ecosystem. We selected the student projects as our corpus because they are a diverse collection of speculative design proposals developed independently of the present study. This corpus is well-suited for observing how behavioral drivers naturally surface in design ideation. We shortlisted projects related to sustainable mobility in the context of public transport, bicycles and cars after reviewing all project content. We identified 62 projects that directly or indirectly promote sustainable mobility. A direct example is *BussNess*, an innovative autonomous shared mobility service for businesses that offers employees a premium on-road experience. As an indirect example, *Homesafe*, a product service system, creates meaningful mobility by providing customers with the valuable service of knowing the safest way home via a bike app.

Two researchers independently reviewed all identified projects and systematically coded them across multiple dimensions discussed in the paper by Sadeghian et al. [49], such as affective and instrumental attitudes, descriptive and injunctive norms, control beliefs, and perceived behavioral control, as well as additional contextual and motivational factors. These included access to services and infrastructure, awareness of other CO_2 sources, perceived costs, comfort and safety, value-based tradeoffs, and broader societal values and norms. Furthermore, specific mobility-related themes were captured, including joy of driving, product appeal, public transport, electric vehicles, eco-driving, cross-modal mobility, automation, radical mobility concepts, and ride-sharing practices. Following the initial round of coding, a review session was conducted involving two additional researchers, all with backgrounds in HCI. The purpose of this collaborative session was to revisit and critically examine the preliminary coding results. During the call, the group of four jointly discussed the interpretation of each dimension and clarified any ambiguities in the initial coding scheme.

We reviewed the coded project data, conducting a thorough analysis to uncover design strategies and interventions that aligned with and addressed various aspects of the TPB. The TPB dimensions are hereby defined as follows: **Affective Attitude** refers to an individual's emotional evaluation of a behavior, specifically, whether it is **perceived as enjoyable or relaxing**. For example, experiences such as the joy of driving or a calming connection to nature reflect positive affective associations with certain modes of transport. **Instrumental Attitude** relates to beliefs about the **practical benefits of a behavior**, such as its efficiency, safety, or overall utility. **Subjective Norms** concern the perception of whether others within a relevant social group engage in a particular behavior. This includes **social and cultural expectations**, the influence of peers, and the perceived status associated with specific modes of transport. **Control Beliefs** refer to an individual's beliefs about **the presence of facilitators or barriers** that could influence their ability to perform a behavior. For instance, the availability of transport services, access to infrastructure, or technological tools (like apps) were considered under this component. **Perceived Behavioral Control** addresses an individual's **perceived ease or difficulty in performing a behavior**, based on both personal capability and situational context.

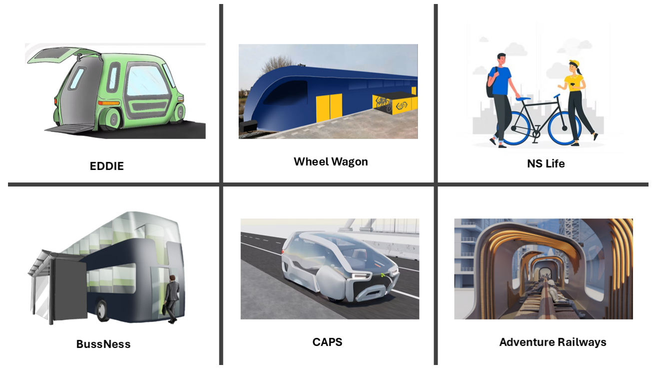

Figure 1: Examples of *Reimagining Mobility project.* [6]

3.2 Results

The aforementioned process enabled the abstraction of higher-level themes, which captured how different projects addressed the behavioral, social, and contextual aspects of sustainable mobility. A comprehensive overview of these themes is provided in the following Table 1. These findings were later translated into scenario elements for Section 4 and allowed empirical testing of how users respond to affective, instrumental, and control-based design cues.

Affective Attitude: The theme of aesthetics and luxury appeared in the use of elegant forms, materials, and premium design elements that aimed to elevate the experience. Designs also emphasized relatedness and social connection, with interventions fostering social interaction, or a sense of community. A number of projects incorporated elements of play, augmented reality (AR) and virtual reality (VR) interactions, and visually engaging components with the objective of gamifying mobility and enhancing its appeal. A connection to nature was also a recurring consideration, with several designs featuring large panoramic windows that offered views of surrounding greenery, incorporated nature-related sounds, and emphasized a sense of openness and connection to the outside world, moving away from the feeling of being enclosed in a transport box. *Instrumental Attitude*: Many projects addressed security, offering protective features related to physical safety, baggage

[5] https://reimaginingmobility.wordpress.com/
[6] Sources (left to right): EDDIE: https://josjesmulders.wixsite.com/my-site-1, BussNess: https://bussness-ontheroad.my.canva.site/, Wheel Wagon: https://xd.adobe.com/view/be96a799-f0ab-427b-b828-e03f8e68ff3b-ebc5/?fullscreen, CAPS: https://capsreimageningmob.wixsite.com/caps, NS Life: https://iremtijhuis99.wixsite.com/website, Adventure Railways: https://adventurerailways.wordpress.com/.

Table 1: Themes identified under each TPB dimension

TPB Dimension	Identified Themes
Affective Attitude	Aesthetics and luxury, Relatedness and social connection, Fun and stimulation, Connection to nature
Instrumental Attitude	Security, Efficiency (time, cost, effort), Physical comfort (e.g., low noise, minimal distraction), Inclusivity, Accessibility
Descriptive / Injunctive Norms	Following the crowd (social proof), Social status
Control Beliefs	Physical proximity, Access to services (e.g., smartphone apps, nearby transport), Autonomy, Ease of use, In-person support
Perceived Behavioral Control	Individual agency, Collective action, Social comparison

safety, surveillance, or data privacy. Efficiency was another dominant theme, with solutions aimed at reducing travel time, lowering financial cost, or minimizing physical and cognitive effort. Physical comfort emerged in designs focused on ergonomics, and sound insulation. Some projects focused on people with different needs by designing for ease of use for people with different physical abilities or levels of access to technology.

Descriptive and Injunctive Norms: The concept of social proof was evident in interventions that relied on visibility, shared participation, or widespread adoption. In some cases, the projected appeal of the design was tied to social status, with experiences framed as aspirational or fashionable. *Control Beliefs*: Physical proximity was reflected in the proposals that brought mobility solutions closer to users. Access to services was addressed through platforms, infrastructure, or digital tools that enabled seamless interaction. Many projects promoted autonomy by allowing individuals to personalize their mobility experiences or exercise choice within systems. Ease of use was a recurring design priority, with many projects emphasizing intuitive interfaces and simplified processes. Some proposals also incorporated in-person support, especially in cases where digital interaction alone might not be sufficient. *Perceived Behavioral Control*: Only a few projects explored aspects related to perceived behavioral control, for example, on how individuals or communities feel empowered to make mobility choices.

4 Study 2: Exploring Influential Factors in Sustainable Mobility Technology Design

Using the synthesized themes above, we conducted a follow-up study in which participants were presented with hypothetical future mobility scenarios, each reflecting a specific theme under a TPB dimension and asked how likely they would be to switch from their current mode of transportation, why, and how much more (if any) they would be willing to pay for the new option.

4.1 Method

4.1.1 Development of Scenarios. We conducted a between-group vignette study with three experimental conditions: public transport, cycling, and shared e-cars. These modes frequently appeared in the projects from Study 1 as future-oriented alternatives, they were presented as more sustainable options compared to the private car use. For each condition, we developed scenarios aligned with specific themes under the TPB dimensions. To deepen our understanding of participants' perceptions, we conducted follow-up interviews after the survey study. As shown in the example below, two vignettes per mode of transport represented the theme of Fun and Stimulation:

- **Public Transport:**
  - Scenario 1: The public transport includes a VR gaming cabin, where passengers can put on a headset and play games during their commute. Offering a break from routine travel, the experience is designed for quick mental engagement.
  - Scenario 2: Each seat in the public transport is equipped with a personal screen that offers a wide range of interactive games and a curated library of movies, short films, and mini-documentaries. This personal entertainment system turns idle time into fun.
- **Bike:**
  - Scenario 1: As you hit a small uphill stretch, your smartwatch syncs with the cycling app, tracking elevation, speed, and heart rate. You earn points for personal records and unlock badges like "Hill Master" and "New Route Explorer." Each ride feels like a solo challenge, motivating and game-like.
  - Scenario 2: Your fitness app tracks speed, distance, and achievements as you ride your bike. Interactive challenges and virtual rewards turn each trip into a personal game: unlocking badges, beating your own records, and keeping every ride exciting and motivating.
- **Shared E-Car:**
  - In the autonomous shared e-car, colorful dynamic lighting pulses to the beat of your music, and the surround sound system amps up your favorite playlist or podcast. Every ride feels lively and energizing.
  - Scenario 2: The shared e-car features built-in entertainment screens where you can play interactive games, stream movies, or take solo trivia quizzes, turning each ride into an engaging personal experience.

The features described in the scenario texts were heavily inspired by the design directions and concepts developed in the *Reimagining Mobility project* database. Drawing from these projects, two researchers collaboratively formulated the scenario texts. Each scenario was created to reflect only one specific theme corresponding to a TPB dimension. By focusing solely on an isolated theme per scenario, we aimed to examine its influence without introducing overlap or interference from other themes. To further refine the scenario texts and ensure that each one strongly reflected a single, isolated theme, we employed an iterative process using ChatGPT-4o. Each scenario was individually fed, along with prompts designed to assess whether the scenario clearly represented its intended thematic focus. The model was prompted to rate the relevance of each scenario across the themes related to a specific TPB dimension, and we probed its responses to identify which specific words or phrases influenced its assessment. Based on this feedback, researchers iteratively adapted the wording of each scenario to enhance clarity and specificity. The final version of each scenario was required to achieve a minimum rating of **8/10** for the intended core thematic element, and **3/10 or lower** for all other dimensions. For instance, when aiming to reduce the influence of *Individual Control*, we modified phrasing from an action-oriented statement such as "you're helping to reduce traffic, fuel use, and local pollution" to a more observational one: "the mobility app highlights statistics on traffic patterns and environmental data." Similarly, to tone down the influence of *Fun and Stimulation*, we softened the emotionally charged language. A scenario that initially included "interactive games and conversation prompts that turn your ride into a shared experience" was revised to "optional prompts for topics during the ride, intended to support interaction if desired." We only used ChatGPT-4o as a formative aid to identify potentially confounding words. All inclusion decisions were based on human reliability and inter-rater agreement. An example of one of the prompt we used is shown below:

> *Assume the concept of Perceived Behavioral Control, which distinguishes between three sub-dimensions: (1) Individual, (2) Collective, and (3) Comparison.*
>
> *In the following scenario of a public transport system, a particular feature is included. Please rate which sub-dimension is addressed and express each dimension with a value between 0–10, where 0 means "not addressed" by the feature at all, and 10 means "fully covered by the feature." Please provide reasons for your answers. Which words had an impact on your rating?*

4.2 Participants

Participants were recruited through Prolific and were required to meet a specific eligibility criterion. All participants were based in Europe and reported that their primary mode of transport for commuting was a personal car. To qualify, they also needed to commute by car at least four days per week. A total of 168 participants completed the study. In terms of age distribution, the majority of participants were between 25 and 44 years old: 55 participants (32.7%) were aged 25–34, and 47 (28.0%) were aged 35–44. Additionally, 32 participants (19.0%) were aged 45–54, 20 (11.9%) were aged 55–64, 8 (4.8%) were aged 18–24, and 6 (3.6%) were over 65 years of age. Regarding gender, 86 participants (51.2%) identified as male, 81 (48.2%) identified as female, and 1 participant (0.6%) preferred not to disclose their gender. Employment status was dominated by full-time employees (129 participants, 76.8%). Concerning commute frequency, 103 participants (61.3%) reported commuting daily by car, 51 (30.4%) commuted a few times a week. Participants received monetary compensation for their participation in accordance with the platform's guidelines.

4.3 Procedure

The between-group study with three experimental conditions included 38 scenario texts per condition. The study was designed and implemented using LimeSurvey and distributed via Prolific. Participants first signed a consent form, followed by a short introduction that encouraged them to imagine the year 2030, where technological advancements have transformed everyday commuting. They were then presented with a randomized sequence of 38 scenarios based on the condition to which they were randomly assigned. After reading each scenario, participants responded to two scale-based questions. The first used a 7-point Likert scale to assess their willingness to switch from their current commuting mode to the one described, ranging from "Extremely unlikely" to "Extremely likely." The second question asked how much more—or less—they would be willing to pay for this alternative compared to their current commute, using a 6-point categorical scale that included options from "I would not be willing to pay more" to "More than 50% more," as well as "I expect it to cost less than my current commute." At the end of the survey, participants were asked to provide basic demographic information, including age, gender, employment status, commuting frequency, access to a personal car, and use of other transport modes. To complement the survey findings, we conducted a follow-up interview study with a subset of participants. From the original pool, we randomly selected 10 individuals to take part in one-hour, in-depth interviews. The aim of these interviews was to gain a richer understanding of participants' everyday travel behaviors and to explore their perspectives on the future mobility scenarios. We began with a discussion of participants' current mobility practices. They were asked to describe their typical weekday and weekend travel routines, the modes of transport they use, and the main destinations of their trips, such as work, errands, or social activities. Participants reflected on what they liked and disliked about their commute, as well as the factors that influenced their travel choices, including time, cost, comfort, weather, and perceived safety. They also discussed whether and under what circumstances they used public transport, cycling, or shared mobility services. Building on this, participants were then introduced to the future mobility scenarios. After each scenario, they were invited to share what they found appealing or unappealing, whether they would consider shifting from their current mode of transport to the proposed option, and what additional features or support systems they would require. In ride-sharing scenarios, they were asked more specifically about the importance of having a choice in co-riders, as well as how shared aspects of a ride, such as music, lighting, or cost splitting, influenced their experience. The interviews concluded with a reflective discussion, in which participants considered whether any of the scenarios addressed their needs and how factors such as comfort, cost, social perception, or sense of control shaped their willingness to adopt new forms of mobility.

4.4 Results

Survey data were analyzed with repeated measures ANOVA, while interviews underwent mixed deductive–inductive thematic analysis.

4.4.1 Survey Results. A repeated measures ANOVA was conducted to evaluate the effects of the within-subjects factor (TPB dimensions) and mode of transport condition on participants' responses. For the willingness-to-switch question, there was a significant main effect of TPB dimensions, $F(4, 660) = 7.92$, $p < .001$, $\eta^2 = .046$, indicating significant differences among the TPB dimensions. Additionally, there was a significant interaction between TPB dimensions and condition, $F(8, 660) = 4.00$, $p < .001$, $\eta^2 = .046$, suggesting that the effect of dimensions varied across conditions. The effect of TPB dimensions changes depending on the type of transportation: public transport, bike, or shared car. This means that different ways of getting around might make people feel or think differently about the behavior. Post-hoc comparisons revealed that the difference in Affective Attitude between public transportation and shared e-car was statistically significant, suggesting that affective features (e.g., aesthetics, fun) were less persuasive when embedded in car-sharing scenarios. Conversely, Perceived Behavioral Control remained relatively strong in all conditions, but was highest in the bike condition, possibly reflecting greater perceived personal agency. Post-hoc tests using Bonferroni correction revealed that Affective Attitude significantly differed from multiple other dimensions. Specifically, Affective Attitude were significantly lower than Instrumental Attitude (Mean Diff = −0.20, $p = .012$), Descriptive Injunctive Norms (Mean Diff = −0.28, $p = .002$), Control Belief (Mean Diff = −0.30, $p < .001$), and Perceived Behavioral Control (Mean Diff = −0.27, $p = .002$). This suggests that not all TPB dimensions are perceived equally by participants, especially Affective Attitude is rated lower than others. No other pairwise differences among the remaining dimensions were statistically significant ($p > .05$). As shown in Table 2, we calculated descriptive statistics for each of the TPB dimensions, for the willingness-to-switch question, mean scores for Affective Attitude decreased across conditions (M = 4.24, 3.97, and 3.57 for public transport, bike, and shared e-car, respectively), indicating a decline in favorability. In contrast, Instrumental Attitude (M = 4.12, 4.21, 4.06) and Control Belief (M = 4.18, 4.23, 4.28) remained relatively stable and higher than Affective Attitude. Descriptive Injunctive Norms (M = 4.21, 4.32, 4.10) and Perceived Behavioral Control (M = 4.23, 4.30, 4.05) also showed minor fluctuations, suggesting limited variation across conditions. For the willingness-to-pay-more question, there was a significant main effect of condition, $F(2, 165) = 9.08$, $p < .001$, $\eta^2 = .099$, indicating that participants' responses differed significantly across the three conditions. A similar pattern was observed, with the lowest means found in the Bike condition across all constructs. For example, Affective Attitude dropped to a mean of 1.73 in bike condition, compared to 2.09 and 2.07 in public transport and shared e-car, respectively. This trend was mirrored in Instrumental Attitude (M = 2.05, 1.70, 2.10), Descriptive Injunctive Norms (M = 2.06, 1.68, 2.10), and Perceived Behavioral Control (M = 2.10, 1.68, 2.05).

Multiple Linear Regression. We conducted regression analyzes to examine how psychological constructs predicted willingness to switch and willingness to pay more across three transportation modes. The model predicting willingness to switch accounted for 71.2% of the variance in switching behavior ($R^2 = 0.712$, $p < .001$). The most significant predictor was instrumental beliefs ($\beta = 0.456$, $p < .001$), followed by control beliefs ($\beta = 0.267$, $p = .017$). Compared to public transport, participants were significantly less willing to switch to cycling ($\beta = -0.34$, $p = .012$) and shared car ($\beta = -0.64$, $p < .001$). Neither perceived control nor social norms had a significant effect. The model predicting willingness to pay more explained 76.7% of the variance in payment intention ($R^2 = 0.767$, $p < .001$). Instrumental beliefs were again the strongest predictor ($\beta = 0.721$, $p < .001$), followed by perceived control ($\beta = 0.260$, $p = .005$). Our findings emphasize the key role of instrumental reasoning (i.e. usefulness and efficiency) in determining both mode switching and willingness to pay.

Table 2: Descriptive Statistics (M ± SD) for TPB Dimensions Across Transport Modes

TPB Dimension	Public Transport	Bike	Shared E-Car
Affective Attitude	4.24 ± 1.38	3.97 ± 1.37	3.57 ± 1.02
Instrumental Attitude	4.12 ± 1.34	4.21 ± 1.29	4.06 ± 1.25
Descriptive/Injunctive Norms	4.21 ± 1.31	4.32 ± 1.28	4.10 ± 1.39
Control Beliefs	4.18 ± 1.32	4.23 ± 1.29	4.28 ± 1.19
Perceived Behavioral Control	4.23 ± 1.33	4.30 ± 1.27	4.05 ± 1.25

4.4.2 Interview Results. The interviews were conducted online in English using Microsoft Teams and Webex. Each session lasted approximately one hour and was recorded with participants' consent. The recordings were subsequently transcribed verbatim and imported into MAXQDA 24. Two researchers conducted the initial coding of the interview transcripts independently. We applied a combination of deductive and inductive coding: deductive codes were derived from the interview guide (e.g., current mobility practices, factors influencing mode choice, and reactions to mobility scenarios), and inductive codes captured emergent themes raised by participants. After the initial coding round, we met online to discuss the interpretations and discrepancies and to refine the coding scheme. This process led to the development of a shared codebook. Through iterative rounds of coding and discussion, broader thematic categories were identified, as follows:

(1) **Safety and Gendered Mobility Concerns**: Perceptions of safety also influenced mobility choices, with concerns varying according to the time of day, location and mode of travel. A participant highlighted, *"I was like concerned if it would be safe, so that's definitely also plays a role in like choosing the transport and and also very often it's a train stations, I had to use it at night after the concerts, then in the middle of the night and especially as a train didn't come and I needed to wait for the next one and then and then the train station was like completely empty. There's also train station where they don't even have a bathroom or you can not eat anything even. And and there's like literally nothing. And I was very concerned like to be safe. Yes. So yeah, it's a huge thing" -P4.* Some participants described feeling unsafe in certain areas at night, which discouraged them from using bikes, or public transport, for example, one participant said *"it can be dark or not appropriate" -P1.* Ride sharing was viewed with caution, and gender-related considerations highlighted the deep intertwining of safety and mobility decisions. One participant explicitly connected this to gender, explaining, *"if*

I could share my rides with another woman, I would do it very easily. But share the ride with a man that I don't know, I don't think so. I don't like the idea. So, for me, it's very important, as a woman, that we could choose vehicles that were just for women. No way. There's no driver. There is no one that could save me that I could scream [to], even with a security system. For me, and for another woman, for the young women that are most targets, I think it's not safe" -P8. Another reported, *"it would all very much depend on who was driving the car. I've got to admit, because when you've been in bad car accidents, you can kind of. That's the reason why I do tend to drive everywhere. That would probably factor if you knew the person who was going and you knew who was driving you" - P2.*

(2) **Infrastructure and Cultural Norms in Mobility Choices**: Biking was described as a common and practical mode of transport in the context of Netherlands, where strong infrastructure and an established cycling culture support its widespread use. As one participant explained, *"I live in the Netherlands, so we live on bikes" – P9.* In other countries, reliance on public transport was sometimes seen as less attractive due to the distance to the nearest train station or the need for multiple switches to reach a destination. A participant from the countryside of another European country said, *"I would need to go to the city at first to use a train and then yeah, that would also be very inconvenient unfortunately. We have like a bus that you can order in here, but or like nobody uses it. It's it's like for the old people" -P4.* Another participant from Portugal expressed that they personally avoid biking because it feels unsafe and physically difficult in her city, explaining, *"I don't like biking, I would consider biking if the infrastructure improved, like safe bike lanes, and if there was a culture of respecting bikers." – P8.* These comparisons highlight how infrastructure and cultural norms strongly shape which modes are considered convenient and efficient. This aligns with the statistical finding of behavioral control.

(3) **Comfort and Relaxation as Drivers of Mobility Choice**: Comfort and relaxation emerged as key factors shaping participants' attitudes toward mobility experiences. Some mothers of young children saw the ability to use travel time to rest or switch off as highly valuable. As one participant explained, *"if it was genuinely all worked out in regards to your schedule and things like that, then why would you not want to relax on the way up to work? Yeah, so doing it on your commute would make you feel like make most of your time again, feel a bit switched off and relaxed and then like happier at work or happier at home." -P1.* Another participant emphasized that *"comfort is important. More important in the the longer the the the the trip, the the more important it is. Yeah, in short trips, of course it's important, but it's not essential" -P3.* Similarly, participants highlighted comfort as a decisive factor. One participant stated, *"comfort, comfort, I'll say that's the biggest one, when I'm traveling I need to feel comfortable" – P7,* A further participant described public transport as valuable precisely when it enabled both relaxation and productivity, explaining, *"very positive, I love the idea of relaxing, working, or watching films during travel. I would definitely use it if comfort and reliable Wi-Fi/charging existed, and I would be willing to pay more for that" – P10.* Another described their ideal vision of a comfortable, accessible, and quiet train journey as *"a dream come true, everything, the cabins, the silence, the possibility of having a silent travel and focus, or even rest. It is wonderful, I would pay for comfort and silence." – P8.* This reflects instrumental attitude, with comfort being a decisive factor in how participants evaluate mobility options.

(4) **Unsuccessful Features, AI, Gaming, and Artificial Experiences**: Participants did not respond well to certain proposed features. Conversational AI elements were deemed unhelpful, and gaming or screen-based entertainment was deemed irrelevant. One participant reported, *"I'm not sure about the [AI] conversation. It depends if you're in that mood. I suppose if you don't want to listen to anyone, you don't have to kind of take up the conversation. But as long as you've got the option to kind of go in and go out, that's fine" -P2.* Similarly, artificial sounds were considered less appealing than real sensory experiences, such as the sounds of nature. Such features added little value to participants' mobility experiences. Screens in public transport were also generally dismissed, as one participant explained, *"I normally take my own computer or my iPad to do my own activities because I have to work. I have already the TV show that I'm watching. So, I have my own content. I don't normally use those kinds of screens when they are available" – P7.* However, another participant imagined a different use for them, noting they would appreciate the option if the screen could function as an extension of their workspace, *"if I'm allowed to connect my laptop with it, so I can work. So, I have my own working area" – P9.* This is a rejection of affective attitudes and artificial or gamified features in favor of authentic and personally meaningful experiences.

(5) **Practical Barriers Beyond Infrastructure**: Weather emerged as a central barrier to adopting bikes as a daily mode of transport. As one participant noted, *"I think that the weather would be the most important factor preventing me from going by bike every day" -P3.* Cycling is seen as an option that is chosen in certain situations rather than a consistent choice. Another participant said, *"the bikes sound really nice, but again there's so many factors that were mentioned like things like the weather and and things like that" - P1.* In addition to weather, some participants pointed to the physical terrain such as uneven paths, as further constraints that made cycling less attractive or feasible on a daily basis.

(6) **Incentives and Starting Small**: Incentives such as company perks, rewards, or discounts were viewed positively. Participants stated that they would be interested in starting small, such as choosing to bike a couple of times, if tangible benefits were provided. This suggests that external motivators can bring incremental changes. As one participant clarified, *"being a neighborhood project, I think I understood well those little rewards. Yeah, those would be great" -P3.* Another highlighted the appeal of company-based incentives, explaining, *"I really enjoy the part of the company giving perks like priority parking and charging. I think the biggest way to enter the market will be with this kind of perks, and I think this will be something that I will easily change (to)" – P7.*

(7) **Limits of Eco-Narratives in Mobility**: People may resist sustainability narratives in transport when they are framed as moral obligations without offering practical, supportive alternatives. One participant reported *"that's just embellishment. It's not that I don't care about the eco, it's just that wouldn't be the selling point for me. There's better selling points, which is health, fitness, you know, fresh air. Even if the whole UK stopped tomorrow, right, we're only 1% of global emissions, all right" - P6.* The participant elaborated further saying *"doing your bit is a good thing, right? So I always recycle. I don't waste energy, I don't waste water. I am very good at those sort of things. But a bit like we said about having a nice car now and again, right? I am allowed to treat, I am allowed to take the car, aren't I? You know, it's like, I don't feel as though environmental blackmail in that sense works on me, right? That message would work for me. It is not that I am not bothered, it is just that I am realistic about it" - P6.* It highlights the tension between collective environmental goals and individual-level motivations, emphasizing the importance of designing interventions around personally meaningful benefits rather than relying solely on ecological arguments.

Technology alone cannot drive a shift away from car dependency. Although digital tools and innovations can support sustainable mobility, broader changes to infrastructure, affordability, and cultural practices that influence everyday travel behavior are also necessary. Participants appeared to prioritize instrumental attitudes, such as saving time, and reducing costs, as the strongest drivers of their mobility choices. These were followed by considerations of comfort and autonomy, and, to a lesser extent, affective attitudes, such as aesthetic appeal. Injunctive subjective norms, or perceived social expectations, were valued the least. This suggests that practical and self-directed benefits play an important role in shaping behavioral intentions than emotional or socially driven factors.

5 Discussion

In summary, our study indicates that users' willingness for a behavioral change from the car to more sustainable transportation modes was only moderate. Participants consistently valued convenience, autonomy, cost, and time savings factors. Affective attitude, in turn, suggests making the situation even worse, except for the public transport scenario. Willingness to pay more for sustainable alternatives was generally low, in particular, for cycling.

5.1 Psychological Constructs in Mobility Adoption

Despite increased investment in sustainable transportation and digital tools, car use remains prevalent, particularly in Western countries. Our research elucidates the factors that motivate individuals to continue driving. Our results show significant differences across TPB dimensions and conditions, confirming that not all dimensions are perceived equally. Affective Attitude received the lowest ratings in terms of willingness to switch to sustainable modes across all transport types, suggesting that features such as aesthetics or connection to nature are not strong standalone motivators for behavioral change. This aligns with findings from Schoenau and Mueller [50] and Verplanken et al. [55], who argue that affective features are less predictive of actual behavioral choices compared to habitual and cognitive factors. In contrast, Instrumental Attitude, Control Beliefs, and Perceived Behavioral Control scored significantly higher, highlighting that practical considerations such as efficiency, ease of use, and perceived personal or collective agency have greater persuasive weight. This supports earlier work by Haustein and Jensen [31] and Caballero et al. [14], which emphasized the importance of instrumental and control-related dimensions in determining mode-switching intentions. Participants preferred scenarios where mobility options were perceived as time-saving, comfortable, or empowering. Interestingly, Descriptive and Injunctive Norms also scored highly across conditions, which supports the findings from Sadeghian et al. [48], which highlighted how perceived social approval and comparison can motivate more sustainable transport behaviors, especially in digitally mediated settings.

The interviews emphasized the importance of context, strong cycling infrastructure in the Netherlands normalized cycling, whereas poor public transport design, terrain and weather discouraged its adoption elsewhere. These results suggest that behavioral interventions cannot succeed without supportive infrastructure that makes sustainable options convenient, safe and reliable. Participants expressed openness to experimenting with alternatives when supported by small rewards, company perks, or discounts. Our results suggest that technology alone cannot change deeply ingrained mobility behaviors. Instead, interventions must combine incentives with context-sensitive design, providing instrumental benefits such as time, cost and convenience savings, while also supporting comfort, safety and social needs. This finding aligns with previous research stating that even the best-designed and most well-intentioned persuasive technology applications cannot persuade users to engage in desired behaviors if circumstances do not allow or support them [23]. Overall, our findings reinforce that achieving climate goals through mobility change requires more than building better alternatives, it also depends on how these alternatives are perceived, experienced, and embedded into everyday life.

5.2 How to Nudge Users Away from Cars?

Our findings suggest that discouraging car use requires more than just offering alternative transport options. One approach is to make car use less appealing. Participants themselves highlighted how traffic congestion, limited parking and higher costs reduced their willingness to drive, encouraging them to use public transport or cycle when these barriers became too significant. A participant from Portugal said, *" Because of the traffic and because of of parking, of course it's very hard to park in the city center and also the traffic is always jammed, so I avoid it, I avoid my car. Yeah, I try to go by public transport to the metro mainly." -P3.* Policies that increase the effort and expense of driving, such as restricted parking, can therefore change behavior, but only if reliable and affordable alternatives are also in place. At the same time, providing meaningful incentives to 'start small' was identified as important. Company perks, discounts or rewards can lower the threshold for experimenting with cycling or public transport, showing that positive reinforcement can complement restrictions.

5.3 How to bring Users to Bicycles?

Bike scenarios consistently received the lowest ratings in both willingness to switch and willingness to pay more. This suggests that while cycling is often framed as a sustainable choice, it may not align with user expectations around premium features or aspirational identity [28]. For perceived behavioral control, designers should incorporate features that strengthen users' sense of agency, such as adaptable routes or low-barrier access. This reflects findings from both our study and earlier work on digital interventions [12, 20], suggesting that technologies that facilitate autonomy and competence are more likely to succeed. Affective elements such as aesthetics or fun should not be disregarded but should be integrated as secondary features. Our results suggest that such elements are appreciated but insufficient on their own to drive behavior change. Visual appeal, playfulness, and nature-connectedness may enhance user experience but are unlikely to drive adoption on their own. Recent work has argued that transferring bikes into "high-tech products" could lead to more sustainable mobility [44, 56, 57]. Considering our results, this has to be questioned, in particular since users seem not wanting to pay extra for such features.

5.4 Limitations

Hypothetical vignettes rely on users' imagination and may not sufficiently cover how the intended scenarios would unfold in reality. This limits the ecological validity of our experiments. Further, our experiment addressed only European car users, and the results cannot be generalized, drivers would have different attitudes and expectations in other countries and cultures. Also, our self-reported measurement of "willingness to pay" does not translate well into reality. It allows to identify general tendencies, such as that participants expected to pay less when cycling instead of driving. However, how price structure could be informed needs to be investigated in additional experiments. Finally, only long-term studies in real environments will be able to find out which factors have the highest potential to change long-lasting habits.

6 Conclusion

Our study contributes a novel approach to scenario-based behavioral analysis by isolating TPB themes. We explored how dimensions of TPB influence individuals' willingness to shift from private car use to more sustainable modes of transport. By translating future mobility design ideas into well-crafted scenarios, we were able to test which types of persuasive features resonated most with car users. While participants were only moderately willing to switch their current mode of transport, certain cues, particularly those related to instrumental attitudes and perceived control, proved more persuasive than others. Our findings confirm that car use is deeply embedded in users' routines, values, and perceptions of convenience. This highlights that habitual behavior, rather than intention or attitude alone, remains a key barrier to transitions to sustainable mobility. Ultimately, solutions must move beyond isolated persuasive features and aim instead at disrupting ingrained habits of car users. For example, our findings highlight opportunities for policy-oriented design. Building on SHCI's shift from changing individual behavior toward raising policy awareness, our findings suggest ways in which design features might reflect and support transportation policies, such as pricing, parking, and service reliability, when viewed through a Green Policy informatics lens. Expanding on the original question of whether technology (and, consequently, works from HCI communities) can provide an answer: [8, 13], we are afraid we must confirm: Currently, Sustainable HCI in the transportation domain seems to serve its own purpose. If we look for true and honest impact, we need to get out of our "conference zone" and initiate interdisciplinary cooperation with the fields of transport and city planning, general sustainability, climate change, and policy makers. Rather than thinking of isolated solutions on our own, we should bring our unique methods and knowledge to the table to support these communities.

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